SEA TURTLE DIVING BEHAVIOR IN VIRGINIA

2003 Final Report Submitted to:

The U.S. Army Corps of Engineers
Norfolk, VA

By:

Katherine L. Mansfield
John A. Musick

Virginia Institute of Marine Science
School of Marine Science
The College of William and Mary
Gloucester Point, Virginia 23062

January 2004

INTRODUCTION:

The U.S. Army Corps of Engineers (ACOE), Norfolk Division has utilized hopper dredges off the coast of Virginia to obtain sand for placement on oceanfront beaches along Virginia Beach, Virginia. Hopper dredging and beach nourishment are activities which have the potential to adversely affect sea turtles, either directly by encounters with dredging equipment or indirectly by alteration of nesting habitat (Coston-Clements and Hoss, 1983). In 2001, 2002 and 2003, ACOE dredging operations in Thimble Shoals Channel exceeded or came close to exceeding the National Marine Fisheries Service sea turtle incidental take limits for loggerhead turtles (*Caretta caretta*) and Kemp's ridley sea turtles (*Lepidochelys kempi*). This resulted in temporary and/or voluntary cessation of dredge operations and the need for relocation trawling. The threat to Virginia's sea turtles can be minimized by gathering life history data on the sea turtles inhabiting Virginia's waters during the time that dredging operations are in effect. Examining sea turtle residency periods and diving patterns will help determine their vulnerability to different fishing/commercial gears, aiding the development of management approaches that may reduce the number of incidental turtle takes in near-shore fisheries and dredging activities.

The distribution, biology and behavior of sea turtles are strongly linked to the thermal regimes of a turtle's environment (Spotila et al., 1997). Temperatures within any given environment can vary geographically, seasonally, or by depth. With the exception of leatherbacks, sea turtles are not efficient thermoregulators (Zug et al., 2001). Loggerhead sea turtles can only exceed ambient water temperatures by 1° or 2° C (Zug et al., 2001), and therefore must compensate for their inability to thermoregulate via other mechanisms, including habitat selection and temporal/seasonal changes in activity (Zug et al., 2001). Virginia's estuarine and coastal waters are subject to a large range of temperature regimes over the course of four seasons. Temperatures in winter get as low as 1º C, while summer Bay temperatures may reach 30º C. Sea turtles are resident in Virginia waters between May and November (Lutcavage, 1981, Musick et al., 1984), with a few strandings occurring as early as mid-April or as late as December. Analysis of sea surface temperatures during residency seasons indicate that turtles first migrate into Virginia's waters when sea temperatures warm to approximately 18º C (Bellmund et al., 1987; Byles, 1988; Keinath et al., 1987; Musick, 1988; Keinath, 1993; Coles, 1999). When sea surface temperatures drop in the fall, turtles will begin their southern migration out of the Bay and coastal waters, over-wintering in waters ranging from North Carolina south to Georgia, Florida and the Gulf of Mexico (Keinath, 1993; Mansfield et al., 2001). Prolonged exposure to temperatures lower than 8° to 10° C may result in cold stunning, or a disruption in the turtle's metabolic pathways, resulting in loss of buoyancy and inability to dive or swim (Spotila et al., 1997).

Each year, between 200 and 400 sea turtle stranding deaths on average are recorded within Virginia's waters. The vast majority of these strandings are juvenile loggerhead and Kemp's ridley sea turtles. Between 55% and 60% of annual strandings occur in the spring, within a two to three week period when sea turtles are first migrating into state waters (Mansfield et al., 2002). Surface water temperatures typically range between 22° and 23° C during this spring peak in strandings. These sea turtle mortalities may be attributed to a variety of fishing and commercial operations found within State waters. In recent years, the number of annual sea turtle deaths has been on the rise. This increase may be due in part to either intensified fishing/commercial pressure, or to an increase in the sea turtle population over time.

The VIMS Sea Turtle Research Program has used aerial surveys to determine relative abundance and seasonal distribution of animals found in Chesapeake Bay and coastal waters (Byles, 1988; Keinath, et al., 1987; Keinath and Musick, 1987). Aerial surveys conducted between 1982 and 1985 and 1991 to 1992 indicated that 6,500 to 9,700 turtles are found in Virginia's waters within any given season (Byles, 1988; Musick et al., 1984; Keinath et al., 1987). These estimates were based on the number of aerially observed sea turtles extrapolated to account for the entire Chesapeake Bay. The largest numbers of sea turtles were observed during the spring of the year, implying that the greatest sea turtle abundances occurred within the spring. Sea turtle population estimates for the Chesapeake Bay were not consistently quantified for over ten years due to lack of available funding. Surveys were reinstated during the 2001, 2002 and 2003 seasons. The distribution of sea turtles aerially observed in 2001, 2002 and 2003 were consistent with the distribution of sea turtles observed during VIMS turtle surveys in the 1980's (Mansfield et al., 2002a; 2002b). However, questions remain concerning sea turtle surfacing behavior during these early months.

Byles' radio and sonic tracking work in the 1980's indicates that sea turtles spend 5 to 7% of their time at the surface while foraging in the Bay during the summer months (Byles, 1988). When migrating long distances, loggerhead sea turtles spend 10 to 20% of their time at the surface due to the metabolic costs of migration requiring increased oxygen intake (Byles, 1988). These data were collected by tracking sea turtles with sonic and radio transmitters (Byles, 1988; Keinath, 1993; Musick and Limpus, 1997) during the summer and fall in Chesapeake Bay and coastal waters. However, surfacing behavior may vary with season (Keinath, 1993), particularly early in the residency season when sea temperatures are lower and waters are more stratified—cooler temperatures layered below a shallower warm water layer. To date, few data have been available to describe sea turtle surfacing behavior in the spring when the animals first enter Chesapeake Bay, a time period when aerial density estimates are higher, and strandings rates are highest.

To improve estimates of regional abundance from surface densities, more data are needed on the amount of time turtles are visible on the sea surface throughout their residency in Virginia waters. If it is found that turtles spend significantly more time above the thermocline in the spring, then the likelihood of turtle takes by hopper dredges may be reduced during that season. Thus, the window for turtle safe dredging activities may broaden based on thermocline location, bottom temperature and associated sea turtle diving behavior. This report describes the at-sea movements of the turtles tracked over a period of time up to 24 hours post-release. These data will be related to the potential interaction of sea turtles with dredging operations and beach replenishment.

METHODS:

Between June 16 and August 15, 2003 five sea turtles were outfitted with both VHF radio (Lotek RMMT_3) and acoustic (VEMCO V16TP-5H) transmitters to track their at-sea movements. Turtles were obtained from cooperative poundnet fishermen, the Virginia Sea Turtle Stranding and Salvage Network and from local dredge/relocation trawler operators. Four of these turtles also received UHF satellite transmitters (Telonics SDR-T16). Two radio frequencies were used for the radio transmitters: 148.380 MHz and 149.800 MHz. Each radio tag had a three second pulse rate and was encoded with a unique number in order to identify individual turtles while tracking. Sonic tag frequencies ranged between 60.0 kHz and 85.0 kHz and had a

continuous pulse rate. The sonic transmitters utilized a two-channel coding scheme that synchronized the tags' pulse with a 1150 millisecond interval, followed by to data pulses, repeating this cycle continuously once deployed. The data pulses included real-time temperature (º Celsius) and pressure data that were converted into depth data (meters/second). Prior to tracking, a series of range tests were conducted to determine relative distances of tags from the tracking vessel based on received signal strength. The locations of the turtles were estimated from GPS locations of the tracking vessel and the relative strength and direction of radio and sonic signals relative to the tracking vessel (Pemberton, 2000).

Of the turtles radio tracked, two were juvenile loggerheads and three were juvenile Kemp's ridleys. Prior to tag application, turtles were measured, flipper tagged, and the turtles' scutes were lightly sanded with 100 grit sandpaper and cleaned with acetone. Radio and satellite transmitters were placed on the turtles' carapace at the second vertebral scute. This location provided optimum transmission when the turtles surfaced to breathe. Quick setting Power-Fast™ marine epoxy resin, amine hardener and Fibre Hair Body Filler™ fiberglass resin were used to attach the transmitter to the turtle. Acoustic (sonic) transmitters were placed along the ninth and tenth marginal scute, typically along the left side of the turtle. These transmitters were secured into place using quick setting marine epoxy and/or fiberglass resin.

A Lotek receiver (SRX 400) and an AN-4YG Four Element Yagi antenna were used to monitor the respiratory behavior of the sea turtles through direct observation of radio signals onboard the tracking vessel. Two VEMCO receivers (VR60) and hydrophones (directional VH10 and omni-directional VH65), on loan from the VIMS Shark Program and Jon Lucy were used to track and download real-time temperature and depth data from the sonic tags. One receiver and the directional hydrophone were designated for tracking and bearings of the turtle in-water. The other receiver and omni-directional hydrophone were connected to an on-board laptop to provide a continuous stream of temperature and depth data from deployed tags. VEMCO V-SCAN software was used to receive, convert and archive temperature, depth, and time data.

With the exception of one turtle (#197) all turtles were released in the Bay mouth just outside the Chesapeake Bay Bridge Tunnel (CBBT) within the Thimble Shoal or Chesapeake Channel. Due to heavy seas and easterly winds, one turtle was released just inside the Bay Bridge Tunnel, in the lee of the Eastern Shore/Kiptopeke. Temperature profiles of the water column were taken at the time of release for each turtle using an YSI 600XL Sonde with temperature and conductivity sensors. Turtles were tracked continuously for up to 24 hours post-release. Tracking time was heavily dependent upon weather and sea state. When turtles surfaced to breathe, the radio tags emit a coded signal, based on time intervals of a three second pulse, to the receiver located onboard the tracking vessel (Pemberton, 2000). Radio transmissions cease when the turtle is sub-surface. Ratio of surface to submergence times based on radio telemetry data were calculated for each turtle tracked. One-way analyses of variance (ANOVA) were used to test for differences in surface and dive times among individuals.

Turtles were also tracked when below the surface via acoustic signals emitted by the sonic tags, ensuring that the tracking vessel remain within the signaling range of the turtles' radio transmissions. Real-time temperature and depth data obtained from the acoustic tags were imported into SAS (Version 8e) to parse out the temperature and depth data and to determine the frequency of time spent at different depths or within temperature regimes per turtle.

Four UHF satellite transmitters (Telonics ST-16) were also deployed on the radio tracked turtles, using the attachment methods described above and were supplied at no cost by Rich Brill (National Marine Fisheries Service Cooperative Marine Education and Research Program

representative at VIMS). These tags were used to remotely track the long-term foraging and migration behavior of the sea turtles after radio tracking. Position data were transmitted to National Oceanic and Atmospheric Administration Tiros Satellites when the turtles surfaced to breathe. Tags were programmed with a duty cycle of one day on, two days off, resulting in location and data transmissions occurring every three days. Position data were determined via Doppler shift. The shift in frequency in each signal received by the satellite "indicates the satellite's speed relative to the tag. A tag's bearing is computed based on the ratio of this speed to the satellite's ground speed" (Kenward, 2001). At least two such bearings are needed in order for tag position to be estimated. The accuracy of these positions was determined by the number of bearings (or satellite passes) available per transmission. All position data were sorted based on accuracy codes received with each data transmission. All data were transferred from the NOAA satellites to the ARGOS data processing system, which in turn sent the data in email format to VIMS.

All location (radio/sonic and satellite) data were imported into either ArcView 3.2 (UTM-1983 projection) or MapTool (seaturtle.org, 2002). Kernel analyses for home range were performed on the long-term satellite tracks using the Spatial Analyst and Animal Movement extensions (Hooge et al., 2001). Kernel analyses use "locations of an individual to generate a probability density" (Millspaugh and Marzluff, 2001) based on the frequency distribution of location data over time. Kernel outputs are calculated using the estimated value of the distribution per location point (Millspaugh and Marzluff, 2001). Kernel output contours were set at 95% and 50% confidence levels. The 95% contour is typically used to determine the area the animal actually inhabits or uses, and the 50% contour is used to determine the "core area of activity" (Hooge and Eichenlaub, 1997).

Using Maptool (seaturtle.org, 2002), satellite telemetry locations from the fall movements of satellite tagged turtles were overlaid on NOAA GOES sea surface temperature (SST) datasets from the NOAA NESDIS archives. These datasets provide a six-kilometer spatial distribution of SST. Turtle location counts within different SST ranges were quantified to provide a SST range within which each turtle could be found. Satellite telemetry locations from the fall movements of satellite tagged turtles were also overlaid on bathymetric datasets compiled by the British Oceanographic Data Center. Using Maptool (seaturtle.org, 2002), these location data were quantified to determine the range in depth of the water column within which each turtle traveled.

RESULTS:

The 2003 sea turtle season was a record year for sea turtle strandings: 529 sea turtle strandings were reported for the entire state, not including dredge takes (Figure 1). This number exceeds the previous annual stranding record by over 130 animals and the annual average by approximately 230 animals. The 2003 sea turtle season was also unusual in that Virginia experienced a very late, cold spring. As a result, sea turtles did not enter Virginia's waters in significant numbers until mid-to late June. Peak sea turtle densities recorded by VIMS aerial surveys and the peak in state strandings did not occur until the second and third week in June, well over two to three weeks later than average. The previous record in annual strandings was set in 2001—a year that also had a very late, cold spring. A coastal upwelling event was also recorded off of Virginia's coastline this summer, resulting in water temperatures that were vertically stratified, ranging between 23° and 25° C at the surface and as low as 9° C on the

bottom. These conditions provided a unique opportunity to observe sea turtle dive behavior within very different temperature regimes.

During the 2003 sea turtle residency season, a total of seven sea turtles, three juvenile Kemp's ridleys and four juvenile loggerheads, were tracked using either radio/sonic or satellite telemetry, or a combination of the two (Table 1).

Table 1. Summary data for five sea turtles radio tracked and two sea turtles satellite tracked in/from the Chesapeake Bay, 2003. Tag # represents primary flipper tag number; CC=loggerhead, LK=Kemp's ridley. %T= percent of total time tracked turtle spent at surface; Tag Type R=Radio, S=Satellite.

Turtle #	Species	Tag #	Release Date	Release Location	Hours Radio Tracked	%T	Tag Type
197	LK	XXF723	6/16/03	37.133N; -75.943W	2	7.2%	R
137	CC	XXF731	7/15/03	36.984N; -76.073W	23	36.5%	R,S
205	CC	XXT517	7/17/03	36.985N; -76.071W	13	13.5%	R,S
138	LK*	--PIT--	7/31/03	36.989N; -76.073W	24	16.5%	R,S
168	LK*	--PIT--	8/14/03	36.983N; -76.069W	24	49.2%	R,S
41336	CC	QQN709	10/22/03	36.672N; -75.913W	--	--	S
41335	CC	XXT526	10/22/03	36.672N; -75.913W	--	--	S

*These turtles received a Passive Integrated Transponder (PIT) flipper tag only.

Excluding Turtle #197 who was only tracked for two hours successfully, the mean ratio of surface to submergence time among the turtles was 28.93% (+/-16.49% stdev.). These ratios ranged from 13.5% to 49.2% (Table 1) and are much higher than the ratios observed in 2002 (7% to 12%). The sea turtles tracked during 2003 exhibited a mean daytime surfacing time of 0:01:58 (+/- 0:03:08 stdev.) and a mean daytime dive duration of 0:04:03 (+/-0:01:33) (Table 2). Mean nighttime surfacing time was 0:04:46 (+/- 0:06:19 stdev.) and mean nighttime dive duration was 0:10:59 (+/-0:06:12) (Table 3). The 2003 mean surfacing times are approximately four to five times greater than the combined mean surfacing times observed in 2002 (day: 0:00:34 +/- 0:00:27; night: 0:00:43 +/- 0:00:21).

Among individuals, there were significant differences in surfacing and dive times for both day and nighttime radio telemetry data (ANOVA; p=0.000).

Radio/Sonic Tag #197; Kemp's ridley (juvenile):

Turtle #197 was released June 16, 2003 in 20 feet of water on the eastern Bay side of the CBBT. The curved carapace length of this turtle was 46.1 cm (notch to tip), indicating that it was a juvenile. The turtle was released on a flood tide in one-foot seas off of Latimer Shoals. For the duration of the track, the turtle remained within approximately one mile of its release site (Figure 2). Tracking was aborted approximately four hours after release due to sustained high seas and winds. The turtle was consistently tracked for two of those four hours. Follow-up tracking for this turtle was unsuccessful.

At the time of release, surface temperatures were approximately 20.8º C, and bottom temperatures were approximately 19.3º C (Figure 3). The mean surfacing time for this turtle was 0:00:09 +/- 0:00:05 standard deviation (sdev.). The mean dive period was 0:01:42 (+/- 0:01:39). Minimum surfacing time was 0:00:06; maximum surfacing time was 0:00:24. Minimum dive time was 0:00:06; maximum dive time was 0:09:27. During the successful two hour track post-release, this turtle's radio signal could be heard (indicating that it was within the top meter of water) 7.22% of the time tracked.

Radio/Sonic Tag #137; Satellite Tag #11583; Loggerhead (juvenile):

Turtle #137 was released July 15, 2003 within the Chesapeake Channel on the ocean side of the CBBT. The turtle was released into 32 feet of water. The curved carapace length of turtle #137 was 69.0 cm notch to tip, indicating that it was a juvenile. This turtle initially swam southeast towards Cape Henry with the ebb tide. Once the tide changed, the turtle swam north-northwest through the Chesapeake Channel with the flooding tide (Figure 4), only to head southwest again with the subsequent ebb tide. When last observed after a 24-hour track, the turtle was heading back towards the CBBT via the Chesapeake Channel with the flood tide.

When Turtle #137 was released, surface temperatures were approximately 23.9º C, and bottom temperatures were approximately 18.2º C (Figure 5). Peak surfacing times occurred between 22:00 and 06:00 (Figure 6). After sunset and with the rise of the (close-to) full moon, this turtle spent almost the entire nighttime hours within the first meter or two of water. The mean time spent at the surface was 46 seconds (stdev. +/- 0:04:02) during the day and 0:13:50 (+/- 0:38:41) at night. Mean dive time was 0:05:42 (+/- 0:08:47) during the day and 0:05:31 (+/- 0:04:56) at night. During both the day and night, minimum surface times were six seconds (or one transmission from the radio tag) and maximum length of transmissions were 0:42:45 during the day, 2:40:45 at night. Minimum dive times were 6 seconds during the day and night; maximum dive times were 0:44:31 during the day and 0:16:28 at night (Tables 2 and 3). During the 13-hour track, this turtle's radio signal could be heard (indicating that it was within the top meter of water) 36.45% of the time.

Based on acoustic data, the average depth this turtle could be found was 5.67 meters (+/- 3.28) (Figure 7), however reception of acoustic data was limited during the night due to high seas limiting the range of acoustic tag reception. As a result, the prolonged nighttime surfacing event for this turtle is not reflected in the acoustic depth average. The average temperature was 18.8º C (+/-2.28), with the majority of the acoustic temperature data ranging between 16º C and 18º C (Figure 8).

The satellite track of this animal has continued through January 2004 and the turtle is currently over-wintering south of Cape Hatteras, offshore near the edge of the continental shelf and in the western edge of the Gulf Stream (Figure 9). Prior to its migration south, the turtle established a foraging pattern in the upper Virginia Chesapeake Bay, near and just south of the mouth of the Potomac River. The turtle remained in this region until the first week in October when it swam out of the Bay mouth, remaining just offshore of the lower Eastern Shore until the first week in November when it began its southern migration to its over-wintering grounds off of the North Carolina coast. Kernel home range analysis indicates that the primary foraging home range for this turtle occurred in the waters south of Smith Point and the Potomac River along the western shore of the Chesapeake Bay, represented by the 50% Kernel probability contour (Figure 10). The 50% Kernel represented an area of 87.09 square kilometers. The area within which this

turtle was likely to be found (95% probability Kernel contour) included an area spanning 1,042 square kilometers (Figure 10).

Satellite telemetry locations overlaid on NOAA GOES SST datasets from the NOAA NESDIS archives indicate that the turtle remained within a SST range of 14º C to 23º C (Figure 11) with sea surface temperatures during the turtle's southern migration between 15º C and 20º C. The majority of fall movement occurred within waters with depths ranging between 25 to 50 meters (Figure 12).

Radio/Sonic Tag #205; Satellite Tag #11993; Loggerhead (juvenile)

Turtle #205 was released July 17, 2003 in 25 feet of water on the ocean side of the CBBT, mouth if the Bay. The curved carapace measurement of this turtle was 80.4 cm, indicating that it was a large juvenile. From the point of release, the turtle swam north into the Chesapeake Bay Channel, parallel to and just east of the CBBT as the tide flooded (Figure 13). With the change in tide, the turtle moved with the ebb flow eastward to the Chesapeake Bay Light Tower where it remained through the night hours. The track was broken after 13 hours due to heavy fog and a high level shipping traffic. At the time this turtle was released, surface temperatures were approximately 23.7º C, and bottom temperatures were approximately 21.6º C (Figure 14). At the Chesapeake Bay Light Tower, surface temperatures were 24.5º C, however, bottom temperatures were 11.7º C (data courtesy of the VIMS Longline Survey).

Peak surfacing times occurred three hours post-release (14:00 to 15:00) and between 18:00 and 19:00 (Figure 15). Mean surface time during the day was 0:00:28 (+/-0:00:29), and mean daytime dive time was 0:03:57 (+/-0:4:06). Minimum daytime surface and dive times were six seconds; maximum daytime surface and dive times were 0:02:00 and 0:23:34 respectively (Tables 2 and 3). Mean nighttime surface time was 0:01:01 (+/-0:00:45); mean nighttime dive duration was 0:06:19 (+/-0:05:26). Minimum nighttime surface and dive times were six and eleven seconds respectively; maximum daytime surface and dive times were 0:02:45 and 0:20:56 (Tables 2 and 3). During the 24-hour track, this turtle's radio signal could be heard (indicating that it was within the top meter of water) 13.46% of the time.

This turtle spent a significant period of time within the shipping channels outside of the Bay mouth. As a result, acoustic track had to be broken frequently to allow for shipping traffic. Depth frequency sample size was minimal. The mean temperature within which the turtle remained while at depth was 17.4º C (+/-0.89).

Unfortunately, the long-term movements of this turtle could only be monitored remotely for approximately two weeks post-release due to failure of the satellite tag. The few days following release, the turtle remained in the entrance of the Chesapeake Bay, near the Chesapeake Bay Light Tower, after which it traveled south along the Outer Banks and Cape Hatteras. The last transmissions were received on July 30 offshore of Cape Hatteras (Figure 16).

Radio/Sonic Tag #138; Satellite Tag #11585; Kemp's ridley (juvenile)

Turtle #138 was released July 31, 2003 south of the Chesapeake Channel and just north of the Thimble Shoals Channel on the ocean side of the CBBT. The turtle was released in 26 feet of water. The curved carapace length of turtle #138 was 49.9 cm, indicating that it was a juvenile. Turtle #138 was released on an ebb tide and initially moved with the tidal flow during the first two tidal periods, remaining just east of the CBBT and along the northern edge of the Thimble Shoals Channel and finally moving in to the Chesapeake Bay towards the end of the first flood tide (Figure 17). With the change back to ebb, the turtle exhibited very directed

movement against the tide approximately due west, remaining on this course through the remainder of the 24-hour track.

The turtle was last observed near the northern edge of the James River mouth. At the time of release, sea surface temperatures were approximately 22.6º C and bottom temperatures were 18.2º C (Figure 18). Peak surfacing events occurred between 16:00 and 18:00 (Figure 19). The mean time spent at the surface during the day was 54 seconds (+/- 0:00:52) and 00:01:14 (+/- 0:00:55) at night. Mean dive time was 0:03:44 (+/- 0:03:23) during the day and 0:08:37 (+/- 0:04:08) at night. During both the day and night, minimum surface times were six and seven seconds respectively, and maximum transmissions were 0:04:41 during the day, 0:06:22 at night. Minimum dive times were eight seconds during the day, 0:01:40 at night. Maximum dive times were 0:15:23 during the day and 0:23:29 at night (Tables 2 and 3). During the 24-hour track, this turtle's radio signal could be heard (indicating that it was within the top meter of water) 16.45% of the time.

Based on acoustic data, the average depth this turtle could be found was 5.53 meters (+/- 3.03). The turtle spent more time in deeper waters (6 to 8 meters) during the day than at night (4 to 6meters) (Figure 20). The average temperature where the turtle was found was 21.42º C (+/- 2.27), reflecting the time the turtle spent in the warmer surface layer of water. The majority of the acoustic temperature data ranged between 16º C and 26º C, with a nighttime preference for temperatures between 23º C and 25º C (Figure 21).

The satellite tag attached to this turtle ceased transmitting after approximately one week due to probable tag failure. The recorded location for his turtle was in the mouth of the York River on August 8, 2003 (Figure 22).

Radio/Sonic Tag #168; Loggerhead (juvenile)

Turtle #168 was released August 14, 2003 just south of the Chesapeake Channel on the ocean side of the CBBT. The turtle was released into 25 feet of water. Its curved carapace length was 50.4 cm, indicating that it was a juvenile. This turtle was released with on an ebb tide. Upon release, the turtle exhibited very directed movement (with and against the prevailing tidal flow) east and southeast out of the Bay mouth, then south along parallel to the Virginia Beach shoreline (Figure 23). After a 24-hour track, the turtle was last observed due east of Rudee Inlet.

At the time of turtle release, surface temperatures were approximately 24.4º C, and bottom temperatures were approximately 19.8º C (Figure 24). However, as the turtle moved south along the oceanfront, vertical sea temperature profiles became more stratified. Towards the end of the track (offshore of Rudee Inlet), sea surface temperatures were approximately 21.9º C and bottom temperatures were 10.4º C (Figure 25). Peak surfacing events occurred between 16:00 to 17:00 and 08:00 to 09:00 (Figure 26). The mean time spent at the surface was 0:07:32 (+/- 0:11:26) during the day and 0:12:03 (+/- 0:03:21) at night. Mean dive time was 0:05:10 (+/- 0:06:20) during the day and 0:18:01 (+/-0:07:34) at night. During the day and night, minimum surface times were five seconds and 0:06:34 respectively. Maximum duration of transmissions were 1:09:44 during the day, 0:18:11 at night. Minimum dive times were five and six seconds during the day and night. Maximum dive times were 0:23:00 during the day and 0:23:46 at night (Tables 2 and 3). During the 24-hour track, this turtle's radio signal could be heard (indicating that it was within the top meter of water) 49.19% of the time.

The acoustic data for this turtle indicated that the average depth this turtle could be found was 6.00 meters (+/- 5.82). Unlike Turtle #138, this turtle spent more time in deeper waters (11 to 15 meters) during the night than during the day (7 to 8 meters) (Figure 27). This may be an

artifact of the turtle's movement into deeper shipping channels at night. The average temperature where the turtle was found was 19.9º C (+/-5.82). For the last two-thirds of this turtle's track, it was located in an area of coastal upwelling with 19º C occurring within the top three meters of the water column. The acoustic temperature data ranged between 10º C and 32º C, though the higher end of this range may in part be due to the sonic tag being exposed to air and sunlight. During the night, the turtle spent the majority of its time either near the surface waters within temperatures ranging between 23º and 26º C, or within the bottom few meters in temperatures ranging between 11º C and 15º C (Figure 28).

The satellite track of this animal has continued through January 2004 and the turtle is currently moving south along the east coast of Florida, remaining relatively close inshore (Figure 29). This turtle has remained on a southern migratory track since its release. As a result, kernel home range analyses were not applicable. Satellite telemetry locations overlaid on NOAA GOES SST datasets from the NOAA NESDIS archives indicate that the turtle remained within a SST range of 15º C to 24º C, concentrating between 16º C and 17º C during its fall and winter movement (Figure 30). The majority of fall movement occurred within waters with depths ranging between 10 to 25 meters (Figure 31).

Satellite Tag #41335; Loggerhead (juvenile):

This turtle was previously tagged and released after rehabilitation in 2001 by the National Marine Fisheries Service and Topsail Marine Turtle Hospital in North Carolina after stranding due to difficulty diving. This turtle was recaptured in Virginia's waters in early October, 2003 by relocation trawler operating in the vicinity of the Thimble Shoals Dredge Operations. The turtle was transferred to the Virginia Marine Science Museum for observation, after which it was released with a satellite tag on October 22, 2003 from Back Bay National Wildlife Refuge. At the time of release, this turtle had a curved carapace length of 73.0 cm, indicating that it was a juvenile.

Real-time data tracks for this animal were posted on the seaturtle.org tracking site within a few days of release. For the first week after release, the turtle remained off of the southern Virginia coastline, moving south off of the northern North Carolina coast by the first week in November (Figure 32). The satellite tag ceased transmitting by November 6, 2003. During the two-week track, the turtle remained within a SST range of 17º C to 25º C, with a concentration of movement within 17º C and 18º C (Figure 33). The majority of fall movement occurred within waters with depths ranging between 10 to 25 meters (Figure 34).

Satellite Tag #41336; Loggerhead (juvenile):

Turtle #41336 was also released with a satellite tag from Back Bay National Wildlife Refuge on October 22, 2003. The curved carapace length of this turtle was 72.5 cm, indicating that it was a juvenile. Real-time data tracks for this animal were posted on the seaturtle.org tracking site within a few days of release. Initially, the turtle moved just south of the Virginia/North Carolina border, then up due east of the Chesapeake Bay mouth and southern Eastern Shore. By mid-November, the turtle started moving south, eventually making its way to Cape Hatteras by late November, when the tag ceased transmitting (Figure 35). During the four and a half week track, the turtle remained within a SST range of 15º C to 25º C, with a concentration of movement within 16º C and 18º C (Figure 36). The majority of fall movement occurred within waters with depths ranging between 10 to 25 meters (Figure 37).

DISCUSSION:

Sea turtles are seasonal visitors to Virginia's waters. Due to large fluctuations in temperature between seasons, turtles cannot inhabit Virginia's Bay and coastal waters in the winter as well as early spring or late fall (Coles, 1999). Aerial population and stranding data collected by VIMS in the last 24 years indicate that turtles will not migrate into state waters until sea temperatures reach approximately 18º C in the spring and will migrate south, out of state waters when temperatures drop again in the fall (Coles, 1999). When sea turtles first enter state waters in the spring and during their first few weeks of residency in Virginia, aerial observations indicate that most of the turtles are found in the lower Bay, near the Bay mouth (Byles, 1988; Mansfield et al., 2002a, 2002b). During these first few weeks, stranding counts are historically high, with at least 50% of the annual strandings occurring within a two to three week period between mid-May and mid-June depending upon sea temperatures (Coles, 1999; Mansfield et al. 2002a, 2002b). In the fall, as temperatures drop and sea turtles begin their migration out of state waters, a secondary peak in strandings is often observed, typically beginning mid-September through early to mid-October depending upon sea temperatures (Coles, 1999). Of turtles satellite tracked during the fall migration in 2003, all turtles began their southern migration when sea surface temperatures dropped between 15º and 20º C, and remained within SST's ranging between 16º and 18º C for the duration of their southern migration.

Stranding data for the fall of the year typically do not indicate as great of a stranding peak as in the spring, nor do historic aerial data indicate as large of a concentration of sea turtles in the Bay mouth at this time (Mansfield et al., 2002a; 2002b). However, as turtles move from their Bay foraging grounds out through the Bay mouth, they are at greater risk of encountering dredge operations. Despite cooler bottom temperatures and increased surfacing times of turtles observed in 2003, turtles were still observed to dive to the bottom, particularly at night, regardless of bottom temperatures. Turtles were also taken by hopper dredges based in the lower Chesapeake Bay during the late summer and through the fall during period of fall turtle migration. One option to mitigated these takes may be to cease dredge operations when sea temperatures range between 15º and 20º in the both the spring and fall, or until aerial surveys or satellite tracking data indicate that most sea turtles have either migrated further into the Bay in the spring or out of state waters in the fall.

Despite significant differences in surfacing and dive duration determined by radio telemetry data, all turtles tracked during 2003 exhibited mean surface to submergence rations much greater than the 5% to 7.% mean recorded in the 1980's. The differences observed among individuals in 2003 may be due to species-specific differences, differences in size class and/or variations sea temperature profiles over the course of their track. The 2003 season was also unique in that springtime sea temperatures were cool, delaying the annual emigration of turtles into Virginia waters. Sea temperatures also remained cool throughout the season, with bottom temperatures in the Bay and Bay mouth remaining near 16º C to 19º C for the summer months. This is several degrees lower than the temperatures observed in the 2002 season. Additionally, the coastal upwelling event off of Virginia Beach mid-August introduced bottom temperatures in the low teens to single digits. These low temperatures and the elevated percentage of time that the turtles tracked in 2003 spent at the surface relative to 2002, suggest that turtles preferentially spend more time in warmer surface waters when swimming within a vertically stratified temperature regime.

These data would also suggest that turtles may spend more time at the surface in the spring of the year when vertical temperatures are more stratified that in the warmer months. If

this is the case, then historic population estimates based on aerial survey data have been over estimated. It is critical that this research continue in order to increase our sample size of both different species (loggerhead and Kemp's ridley) and different age classes. Increasing our sample size will strengthen our ability to statistically determine the seasonal or temperature based influences on sea turtle diving and respiratory behavior in Virginia. These data would increase the accuracy of population estimates of turtles in Virginia's waters, contributing to refined take limits per fishery or dredge activity.

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Tables

Tables 2. and 3. 2003 Sea Turtle Surface and Dive Time Summaries based on Radio Telemetry Data

Turtle #	Time	Mean Surface Time	St. Dev.-SURF	Mean Dive Time	St. Dev.-DIVE	Range: Surf. Time	Range: Dive Time
197	**Day**	0:00:09	0:00:05	0:01:42	0:01:39	Min: 0:00:06	Min: 0:00:06
						Max: 0:00:24	Max: 0:09:27
137	**Day**	0:00:46	0:04:02	0:05:42	0:08:47	Min: 0:00:06	Min: 0:00:06
						Max:0:42:45	Max: 0:44:31
205	**Day**	0:00:28	0:00:29	0:03:57	0:04:06	Min: 0:00:06	Min: 0:00:06
						Max:0:02:00	Max: 0:23:34
138	**Day**	0:00:54	0:00:52	0:03:44	0:03:23	Min: 0:00:06	Min: 0:00:08
						Max: 0:04:41	Max: 0:15:23
168	**Day**	0:07:32	0:11:26	0:05:10	0:06:20	Min: 0:00:05	Min: 0:00:05
						Max: 1:09:44	Max: 0:23:00
TOTAL-All Turtles		**0:01:58**	**0:03:08**	**0:04:03**	**0:01:33**		
Turtle #	**Time**	**Mean Surface Time**	**St. Dev.-SURF**	**Mean Dive Time**	**St. Dev Dive**	**Range Surf. Time**	**Range Dive Time**
197	**Night**	n/a	n/a	n/a	n/a	n/a	n/a
137	**Night**	0:13:50	0:38:41	0:05:31	0:04:56	Min: 0:00:06	Min: 0:00:06
						Max: 2:40:45	Max: 0:16:28
205	**Night**	0:01:01	0:00:45	0:06:19	0:05:26	Min: 0:00:06	Min: 0:00:11
						Max: 0:02:45	Max: 0:20:56
138	**Night**	0:01:14	0:00:55	0:08:37	0:04:08	Min: 0:00:07	Min: 0:01:40
						Max: 0:06:22	Max: 0:23:29
168	**Night**	0:12:03	0:03:21	0:18:01	0:07:34	Min: 0:006:34	Min: 0:00:06
						Max: 0:18:11	Max: 0:23:46
TOTAL-All Turtles		**0:04:46**	**0:06:19**	**0:10:59**	**0:06:12**		

Figures

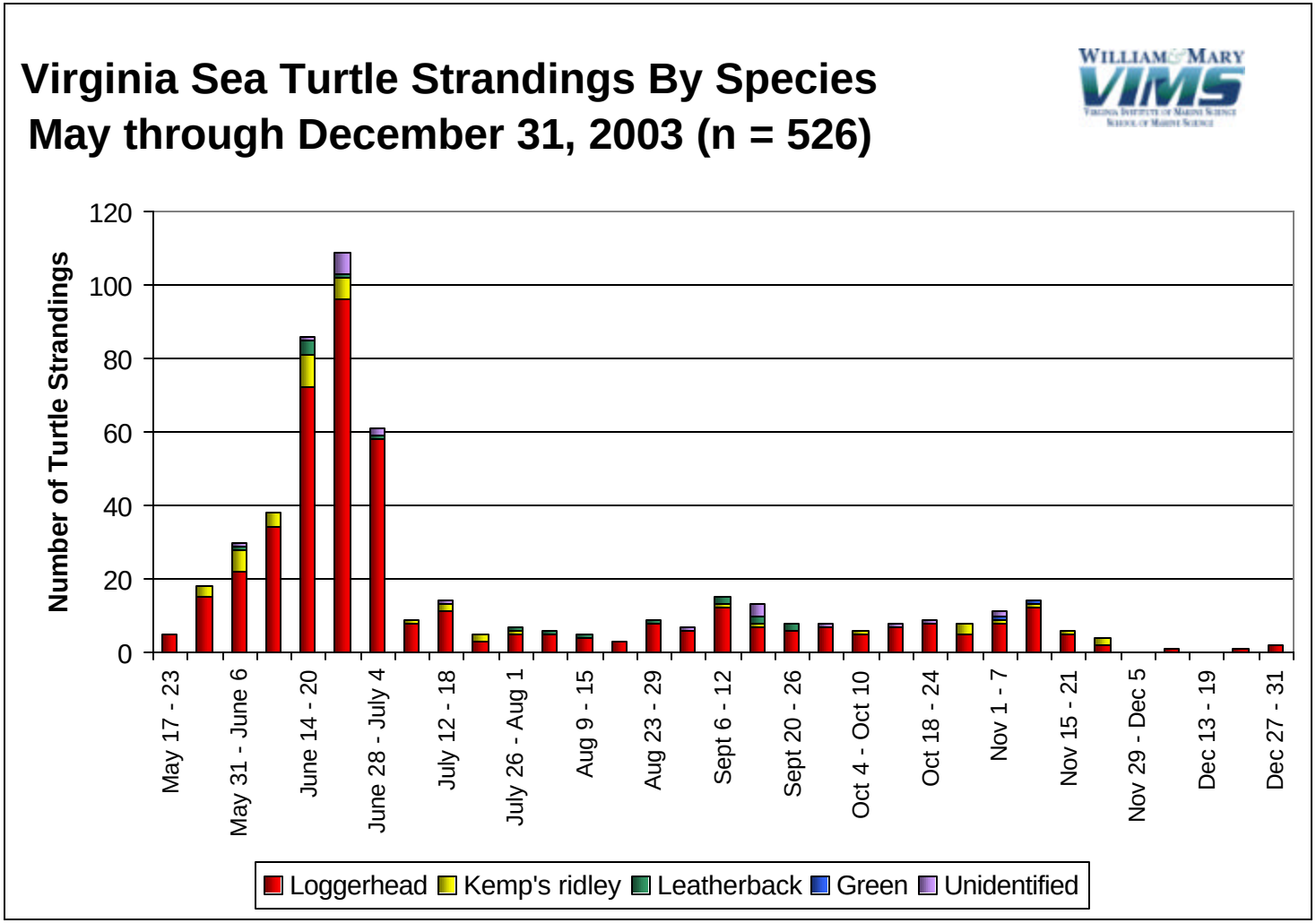

Figure 1. **2003 sea turtle strandings by week and species, May 17 through December 31 (n=526). Note: there were three strandings recorded in March that are not represented on this graph.**

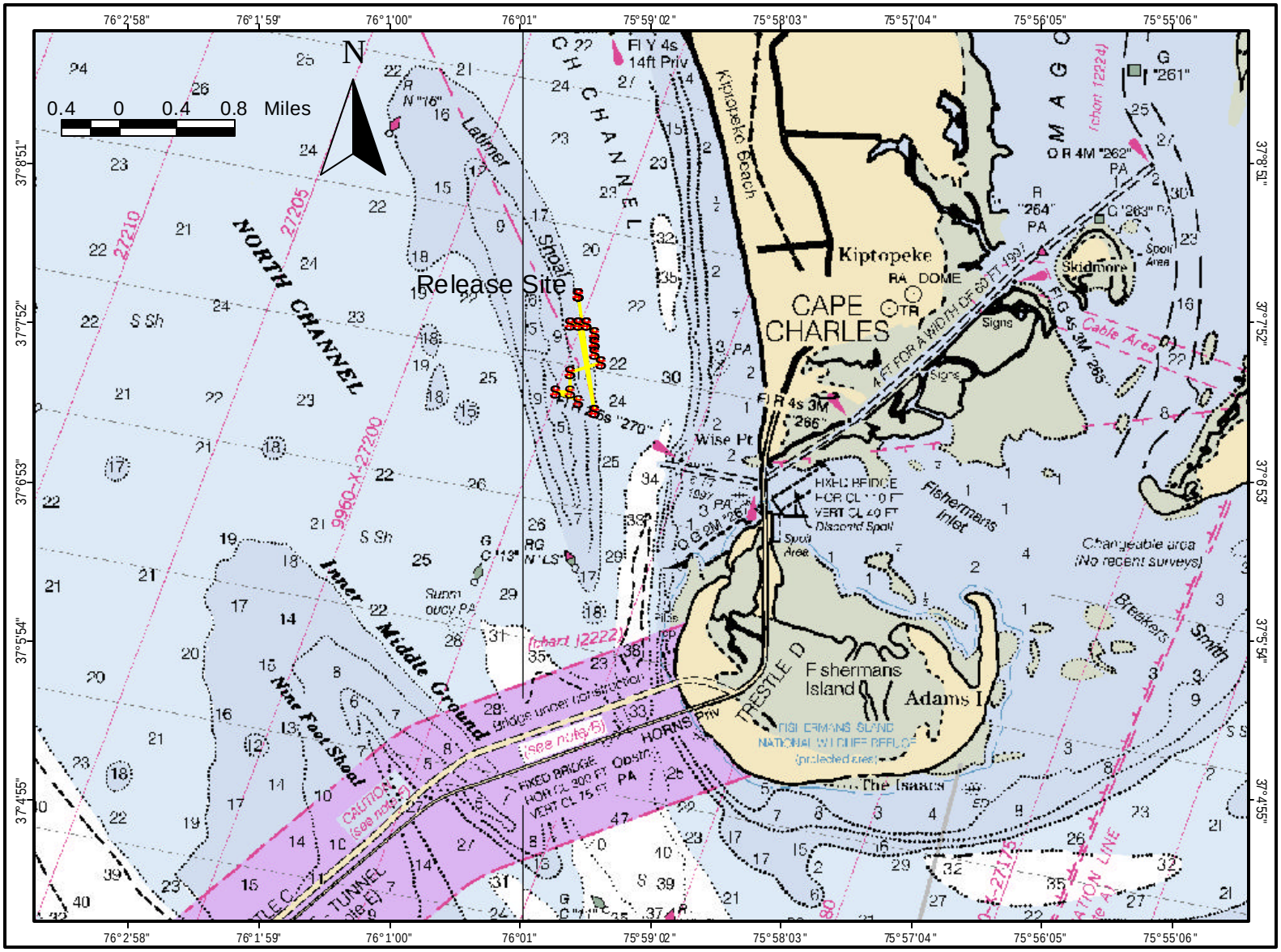

Figure 2. **Post-release movements of turtle #197, radio tracked in the mouth of the Chesapeake Bay for 4-hours June16 to 17, 2003.**

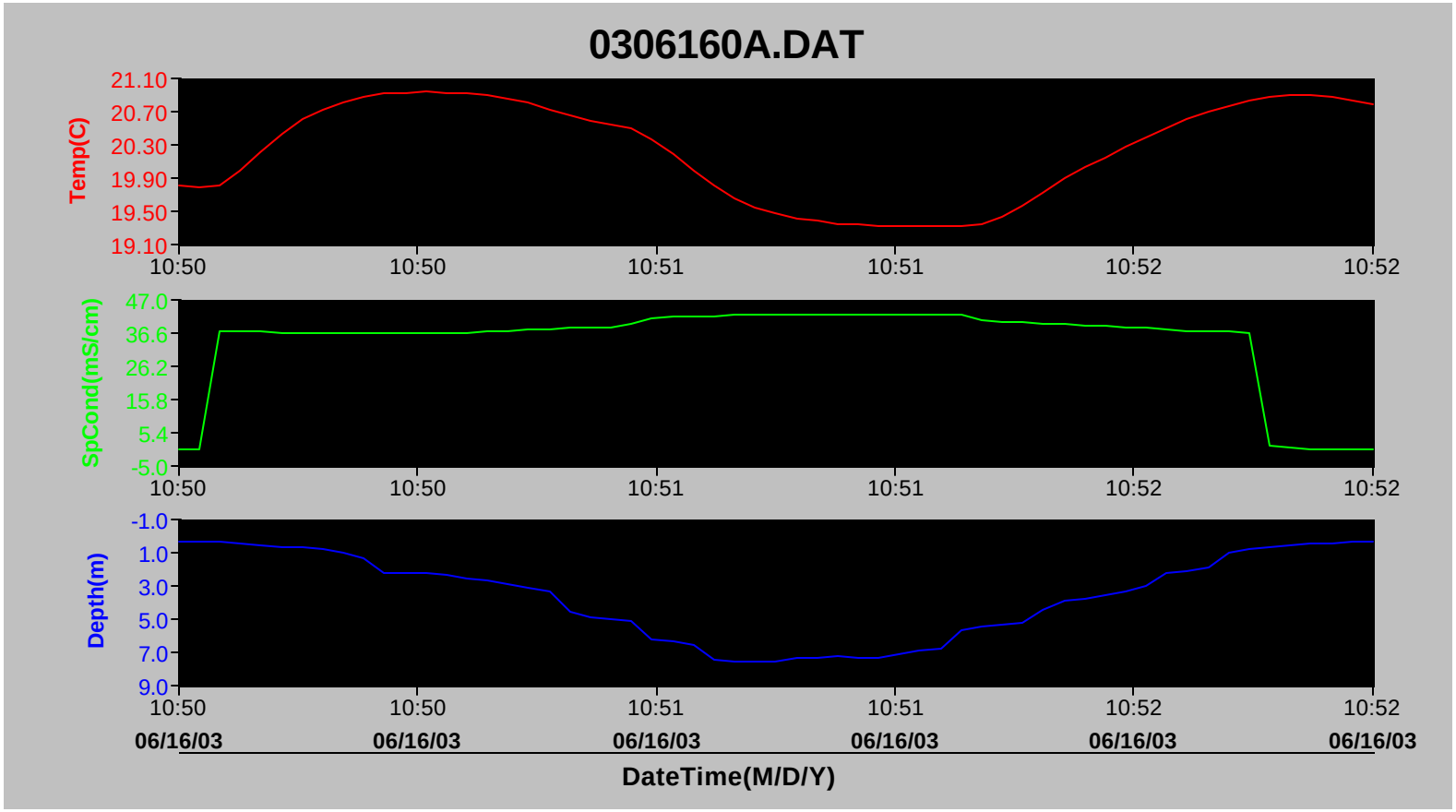

Figure 3. **Temperature, Conductivity and Depth Profile of release site for turtle # 197, June 16, 2003, eastern Bay side of Chesapeake Bay Bridge Tunnel, Chesapeake Bay, VA.**

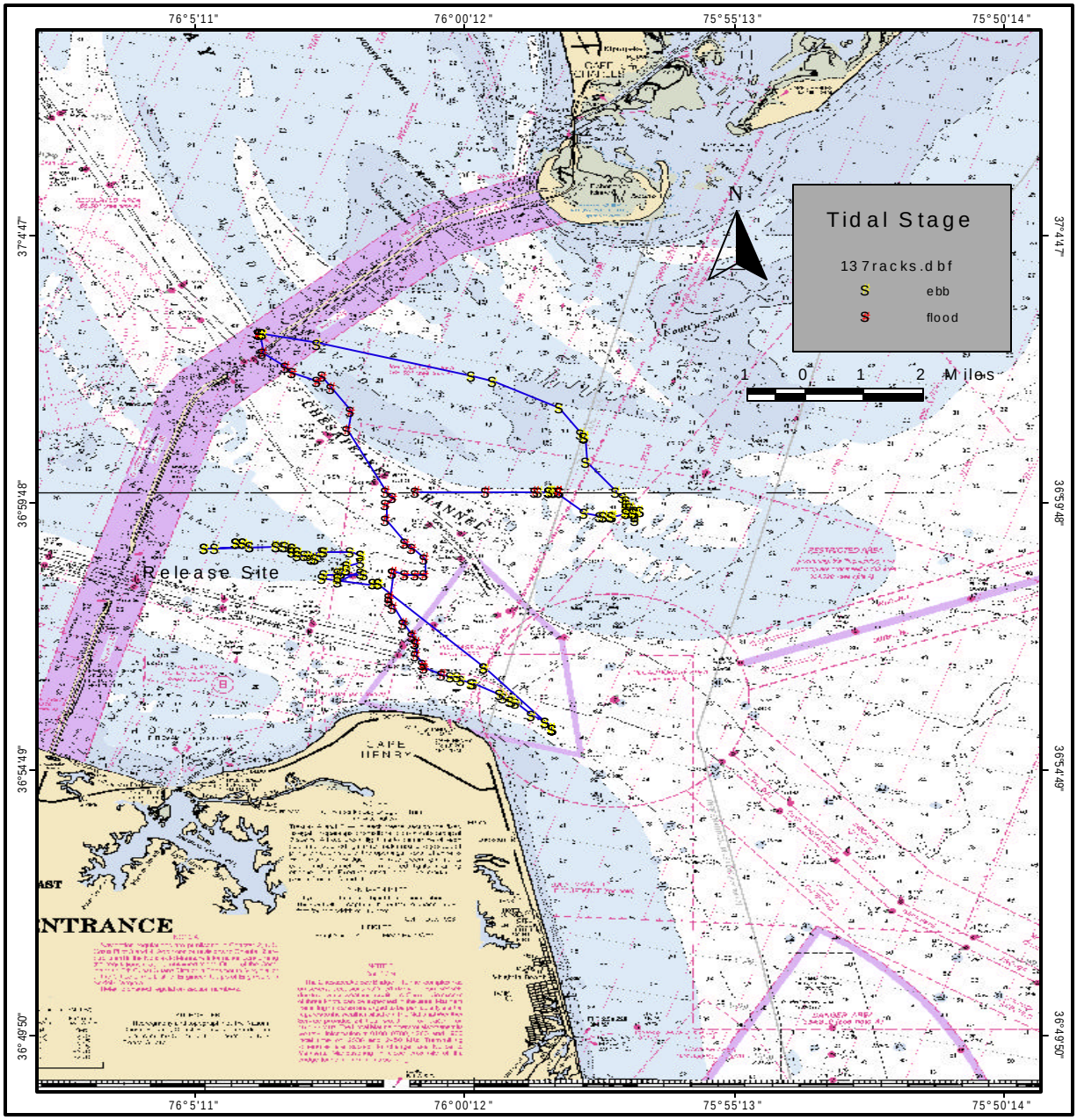

Figure 4. **Post-release movements of turtle #137, radio tracked in the mouth of the Chesapeake Bay for 24-hours July 15 to 16, 2003.**

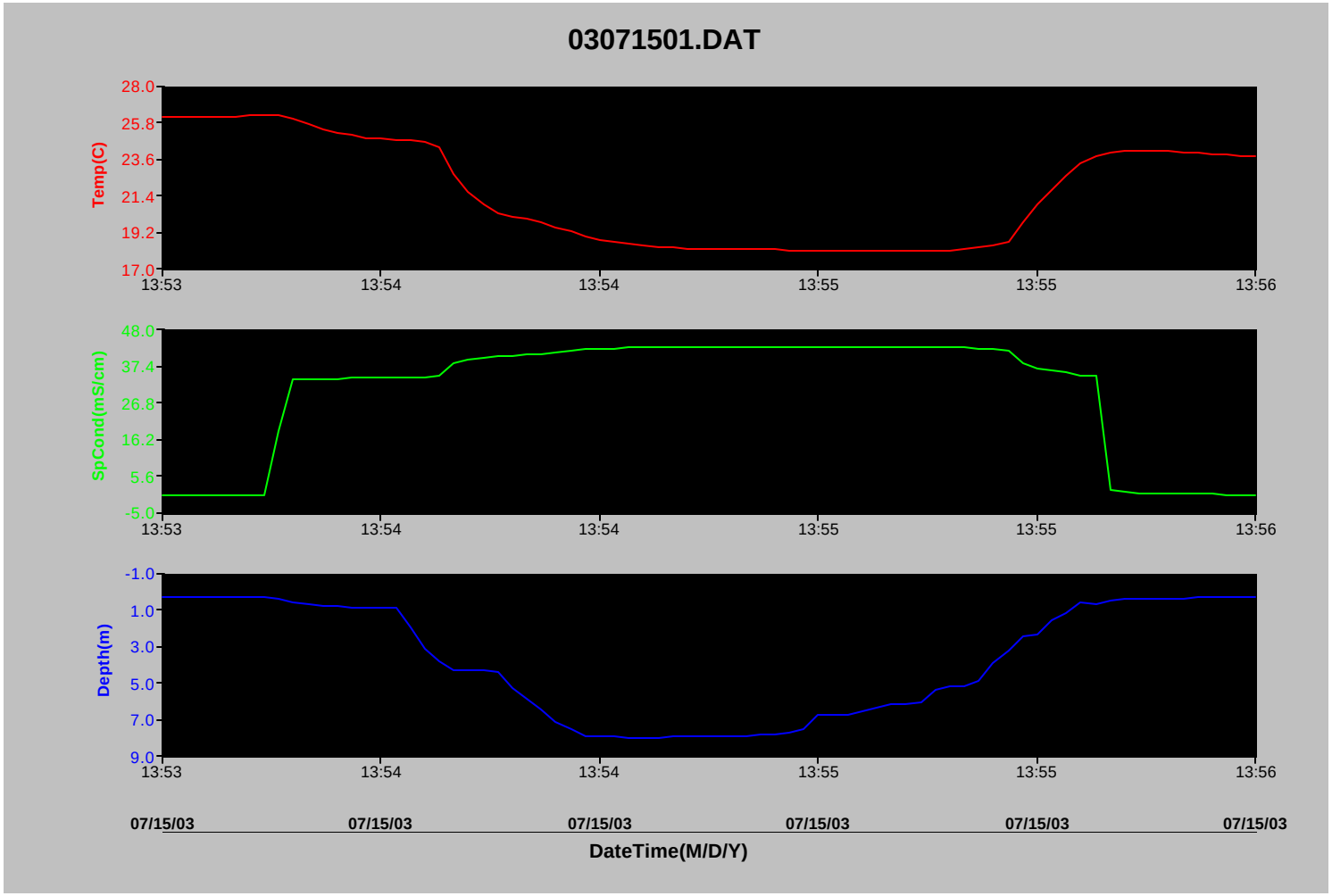

Figure 5. **Temperature, Conductivity and Depth Profile of release site for turtle # 137, July 15, 2003, ocean side of Chesapeake Bay Bridge Tunnel near Thimble Shoals Channel, Chesapeake Bay, VA.**

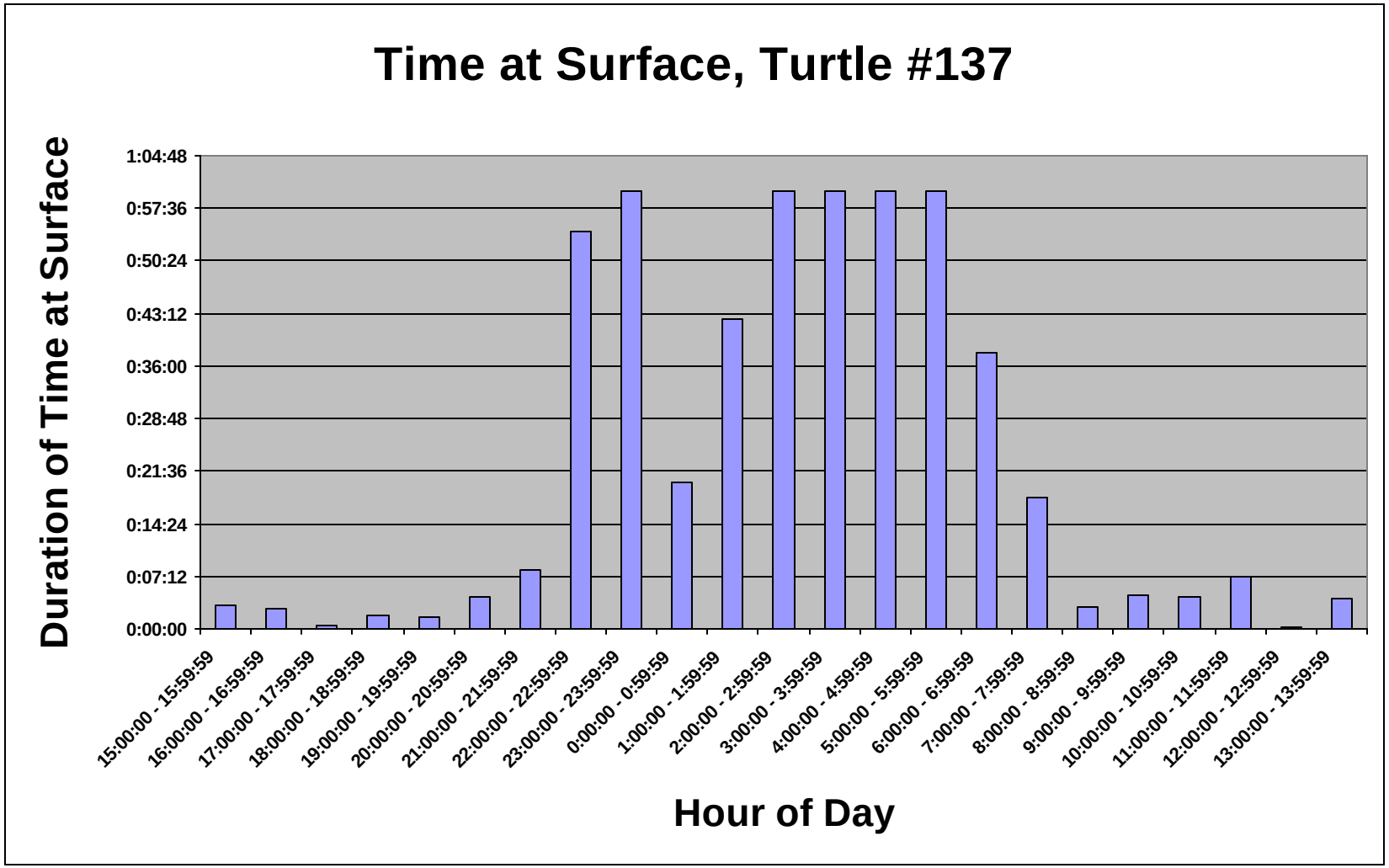

Figure 6. Turtle #137 Surfacing Times, July 15-16, 2003

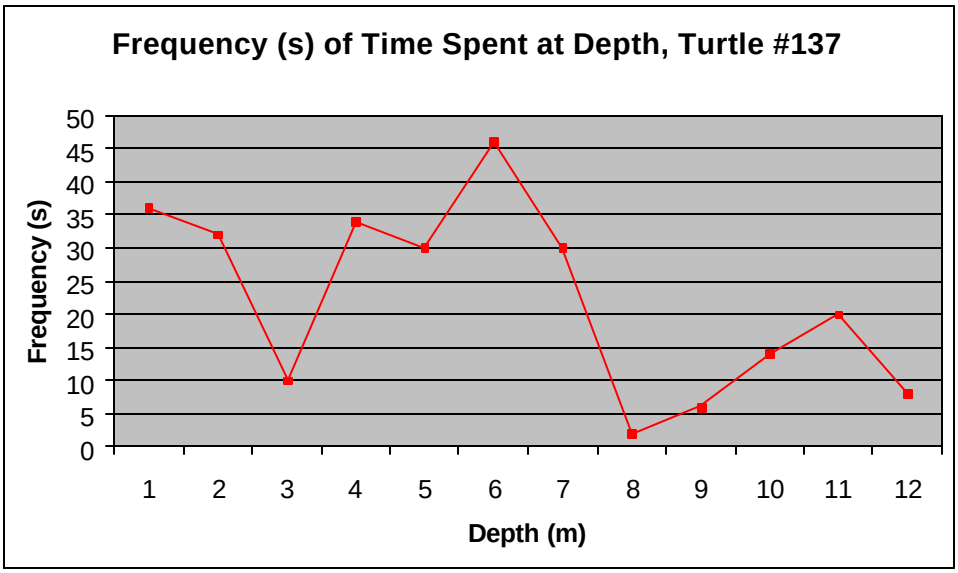

Figure 7. **Frequency if time spent at different depths for turtle # 137 (total track).**

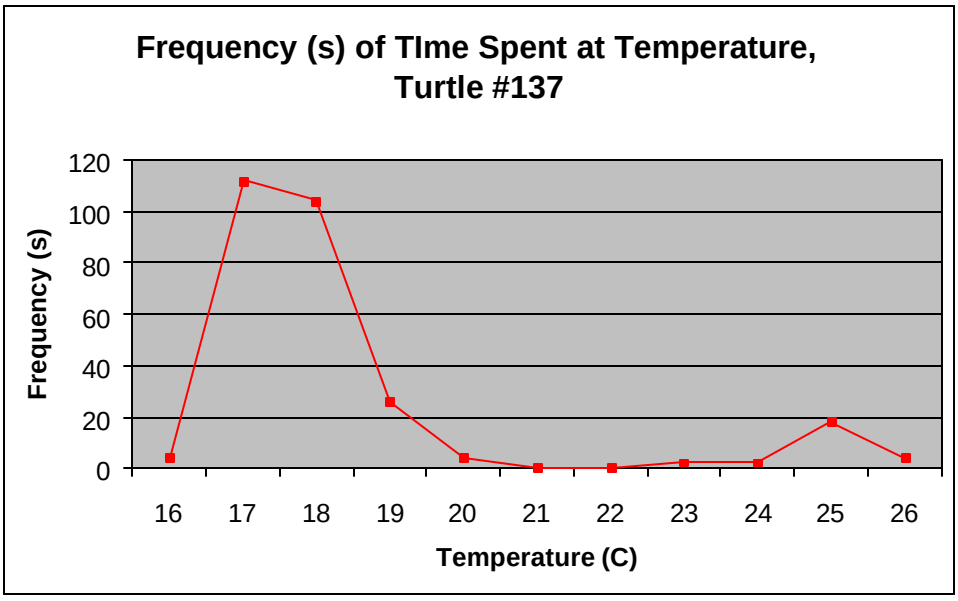

Figure 8. **Frequency if time spent at different temperatures for turtle # 137 (total track).**

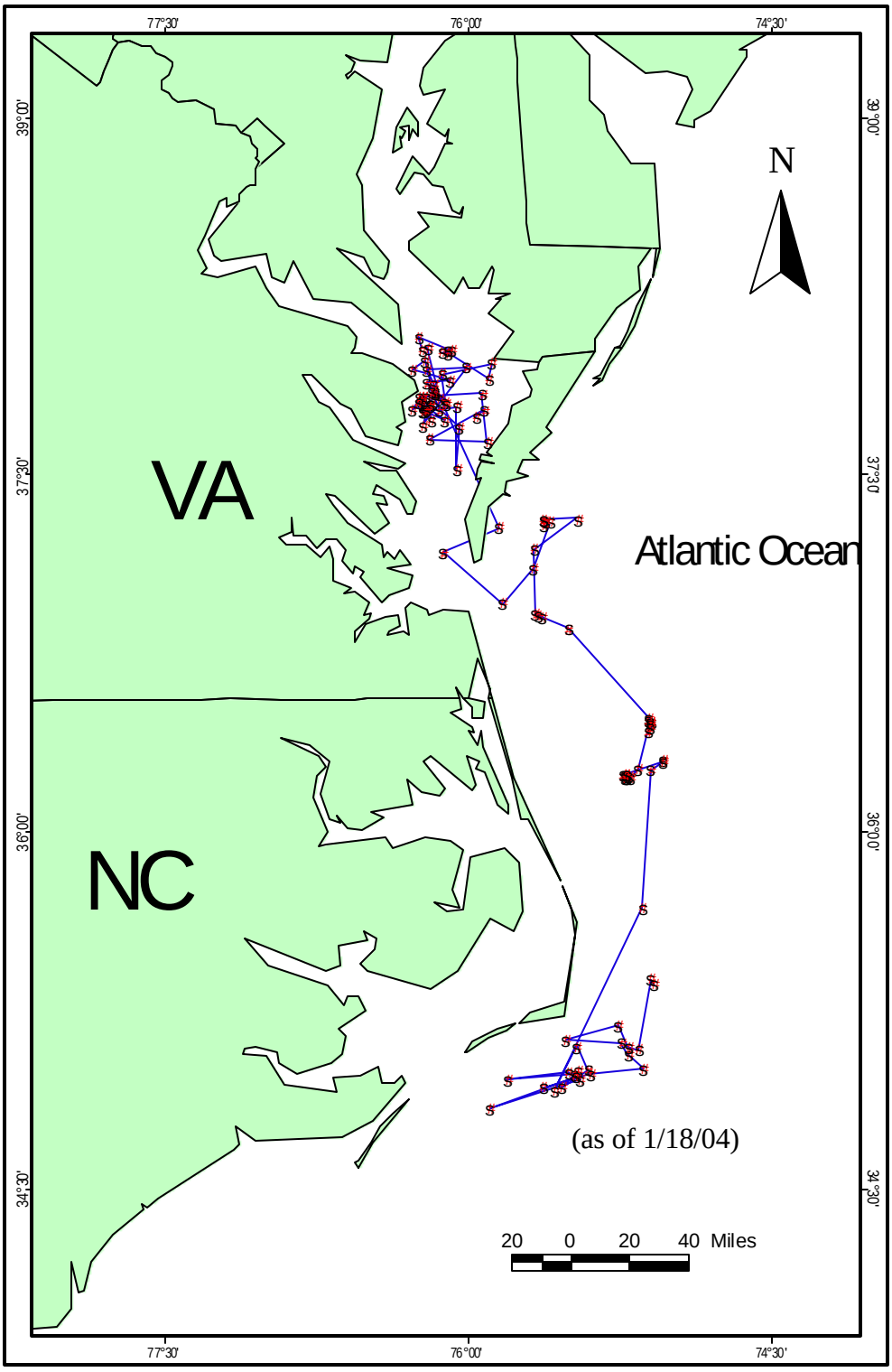

Figure 9. **Satellite tracks of turtle #137, from July 15, 2003 to January 18, 2004.**

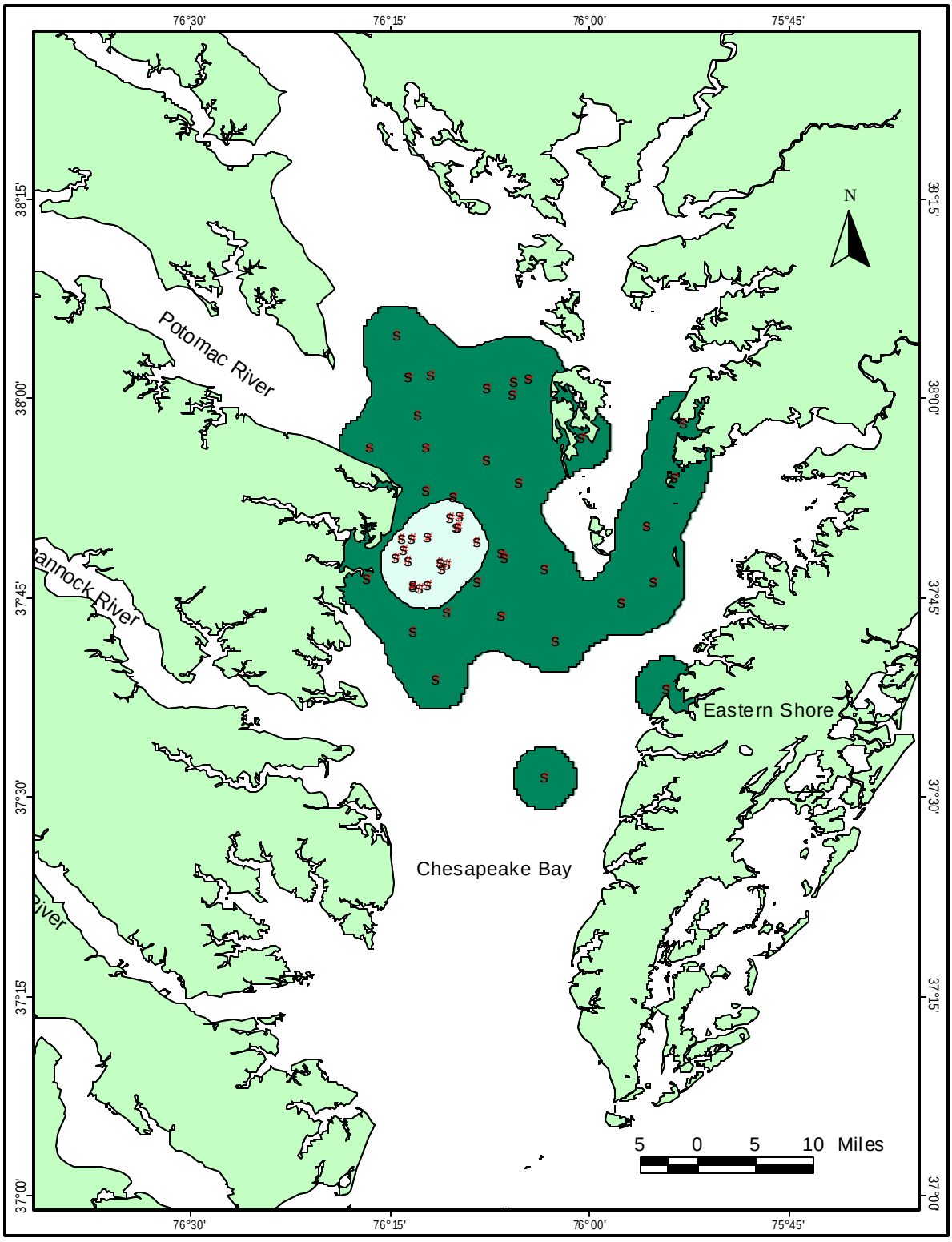

Figure 10. **Kernel home range analysis of turtle #137's satellite tracks while resident in the Chesapeake Bay July 15 to the first week in October, 2003.**

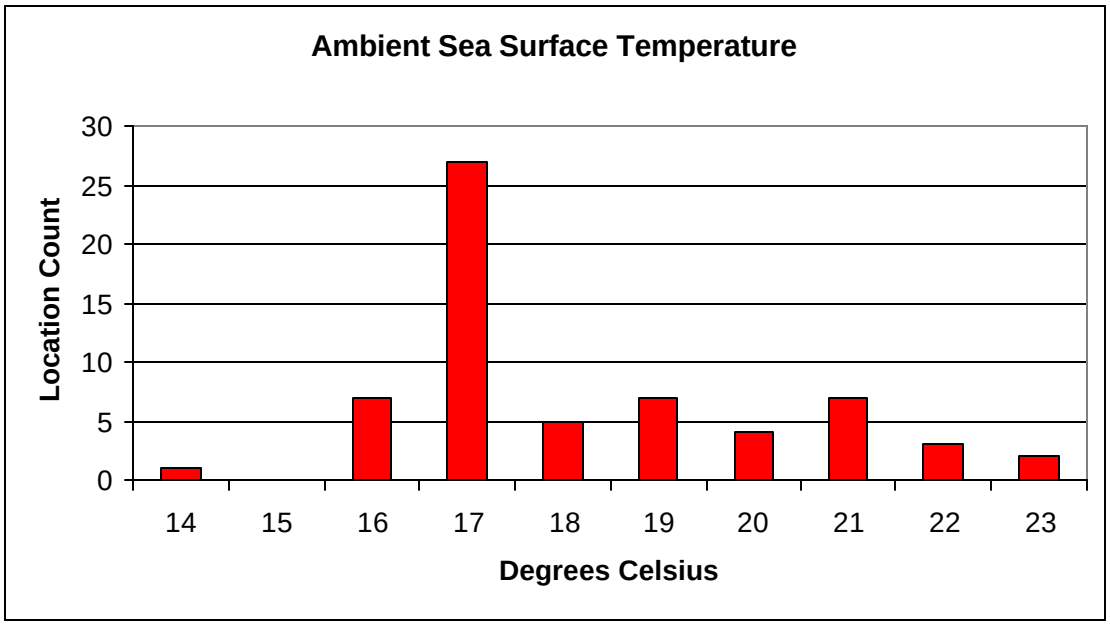

Figure 11. **Counts of satellite telemetry locations for turtle # 137 overlaid on NOAA GOES SST datasets from the NOAA NESDIS archives. Data generated by Maptool (seaturtle.org, 2002)**

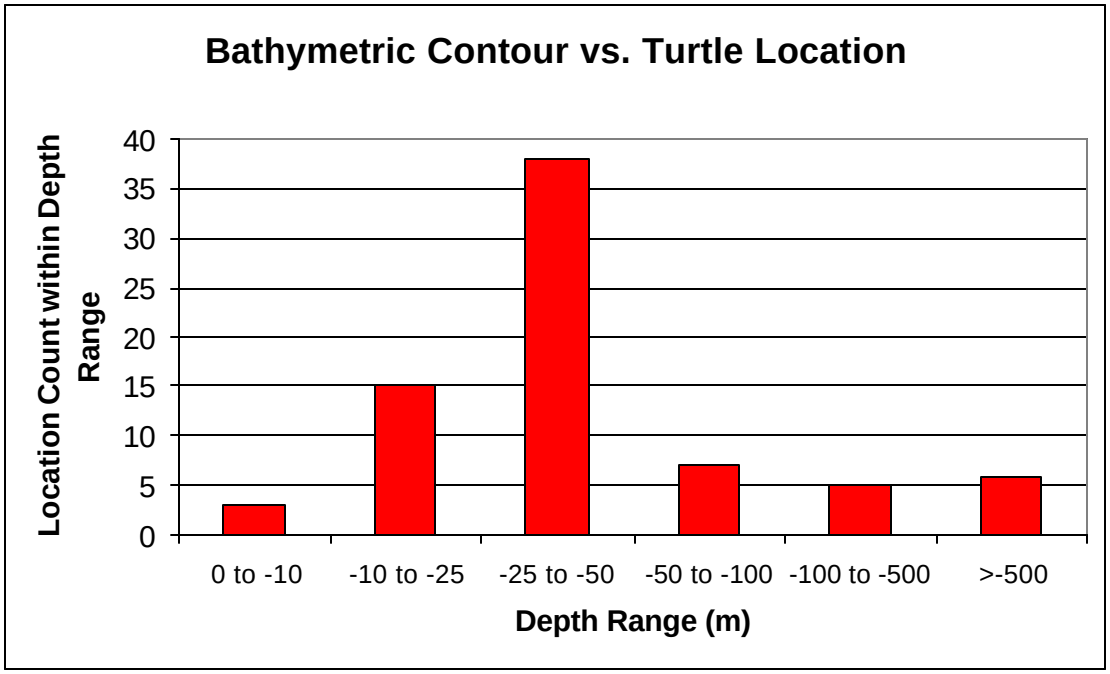

Figure 12. **Counts of satellite telemetry locations for turtle # 137 overlaid bathymetry datasets. Data generated by Maptool (seaturtle.org, 2002)**

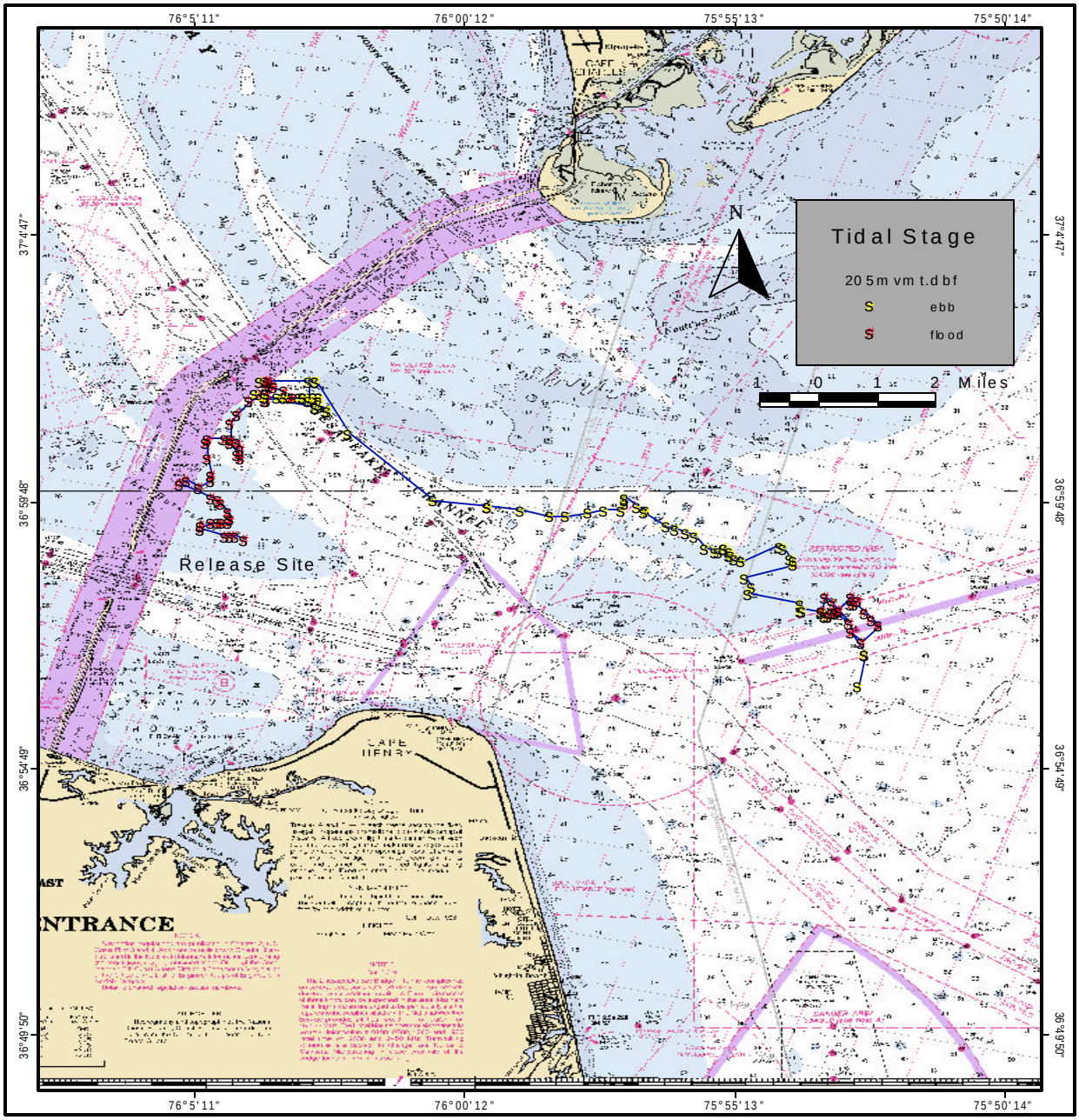

Figure 13. **Post-release movements of turtle #205, radio tracked in the mouth of the Chesapeake Bay for 13-hours July 17 to 18, 2003.**

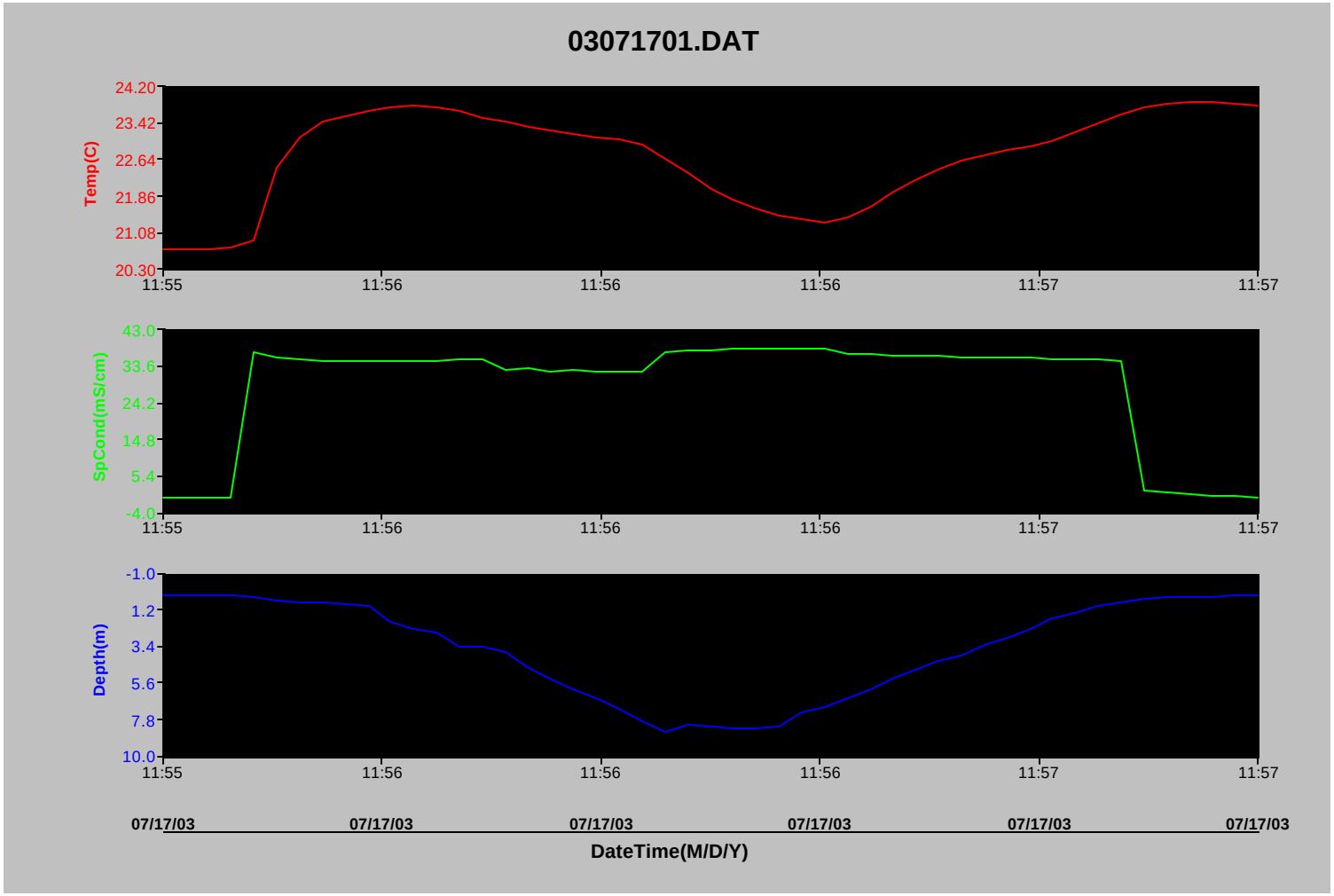

Figure 14. **Temperature, Conductivity and Depth Profile of release site for turtle # 205, July 17, 2003, ocean side of Chesapeake Bay Bridge Tunnel near Thimble Shoals Channel, Chesapeake Bay, VA.**

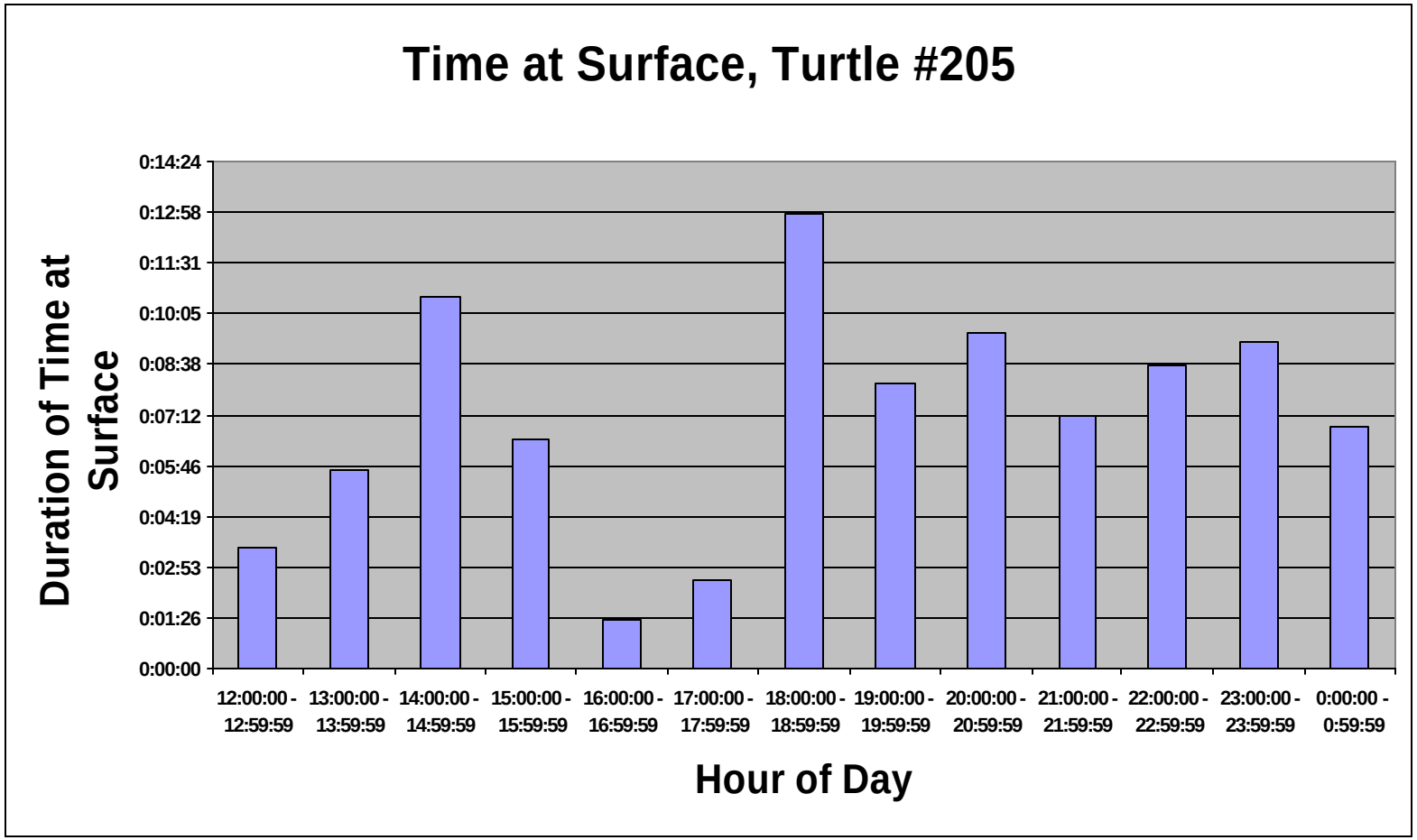

Figure 15. Turtle #205 Surfacing Times, July 17 to 18, 2003

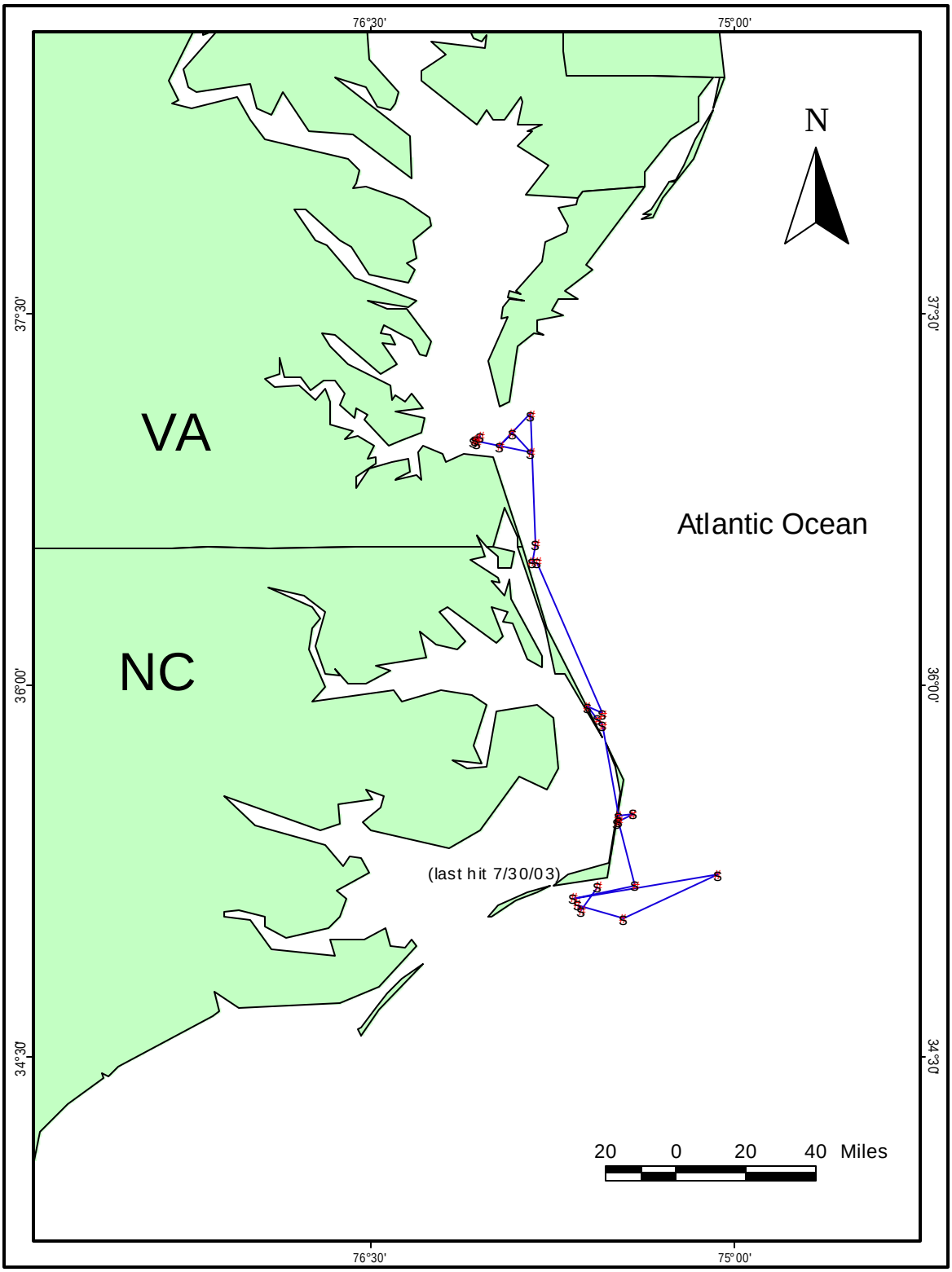

Figure 16. Satellite tracks of turtle #205, from July 17 to 30, 2003.

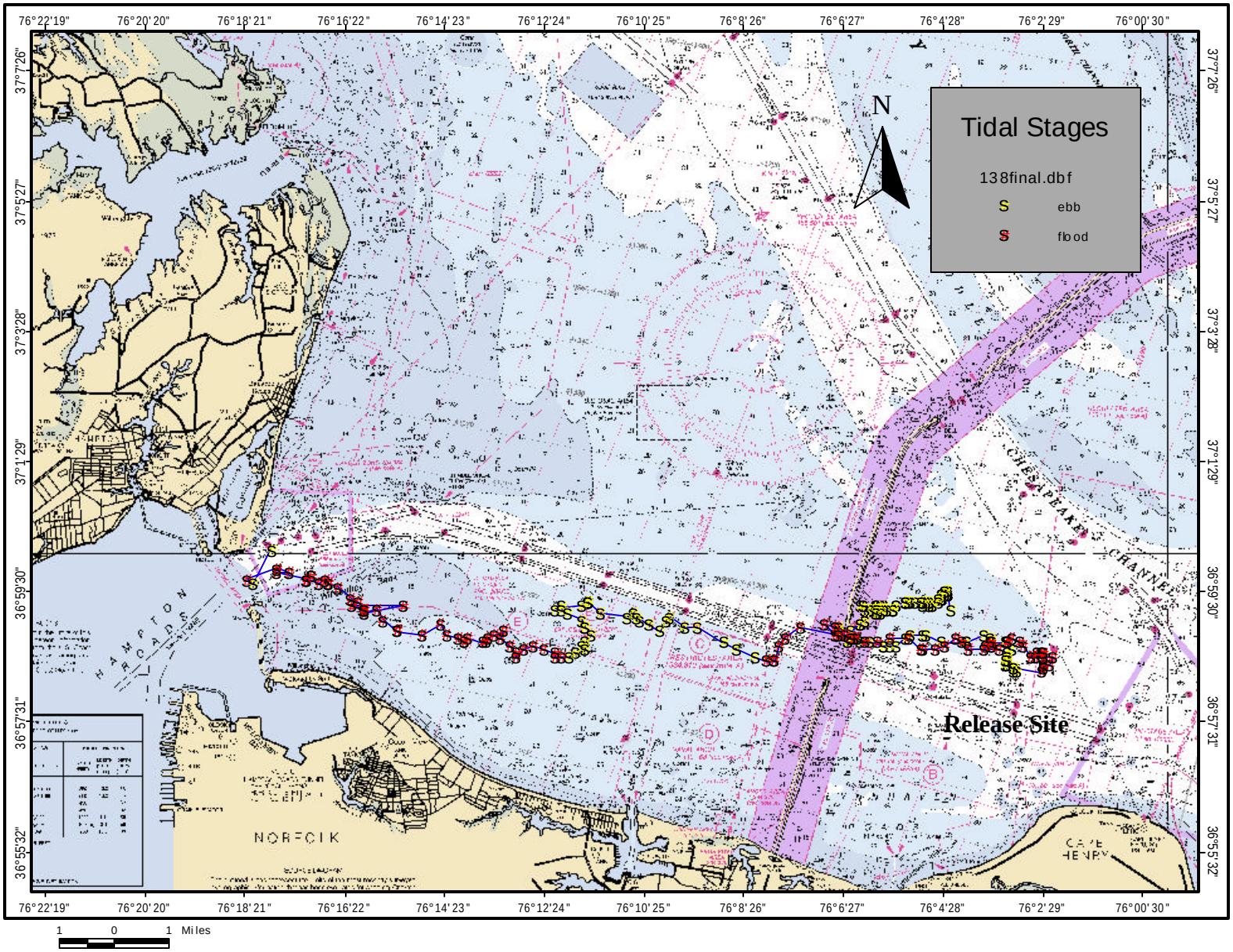

Figure 17. Post-release movements of turtle #138, radio tracked in the mouth of the Chesapeake Bay for 24-hours July 31 to August 1, 2003.

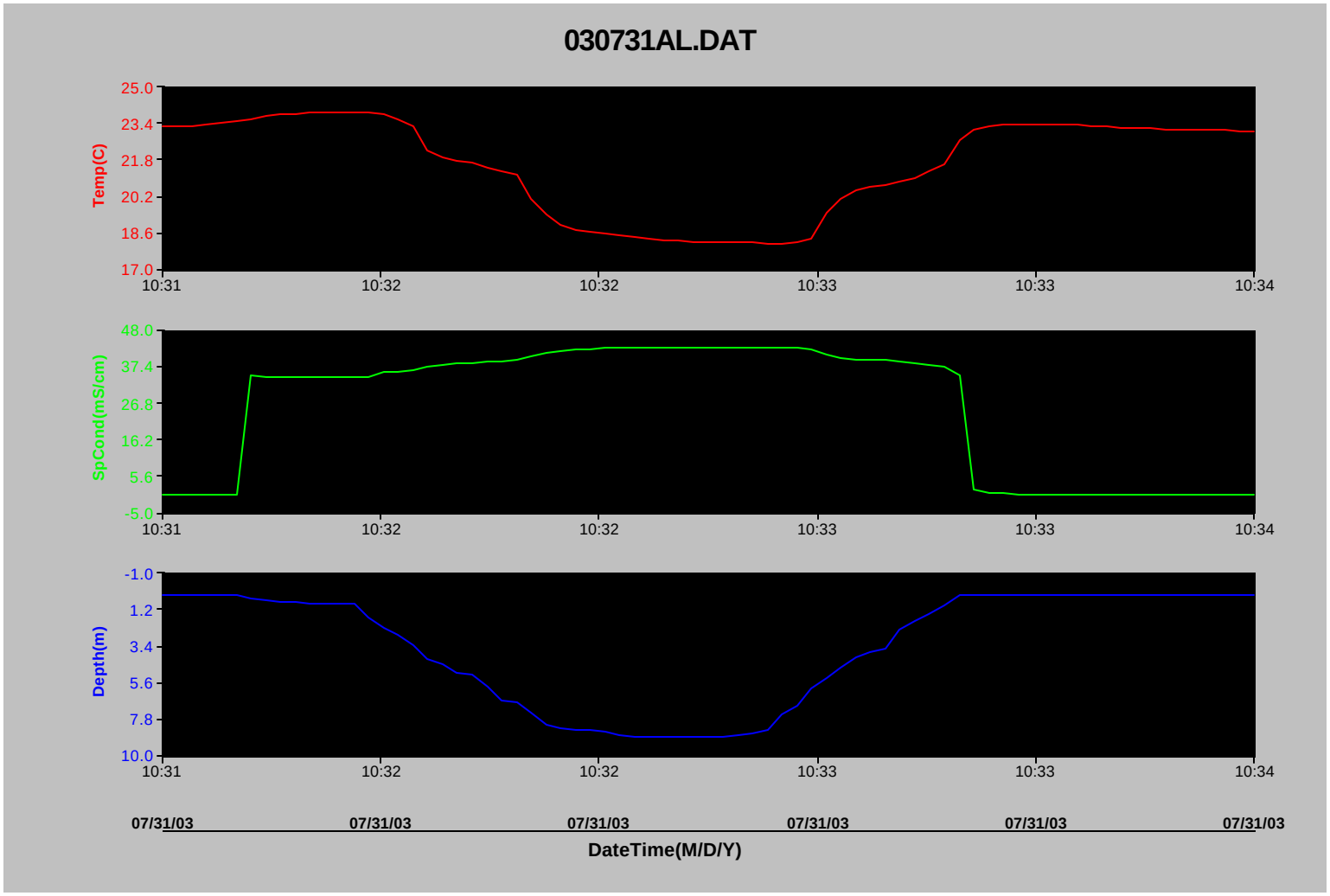

Figure 18. **Temperature, Conductivity and Depth Profile of release site for turtle # 138, July 31, 2003, ocean side of Chesapeake Bay Bridge Tunnel near Thimble Shoals Channel, Chesapeake Bay, VA.**

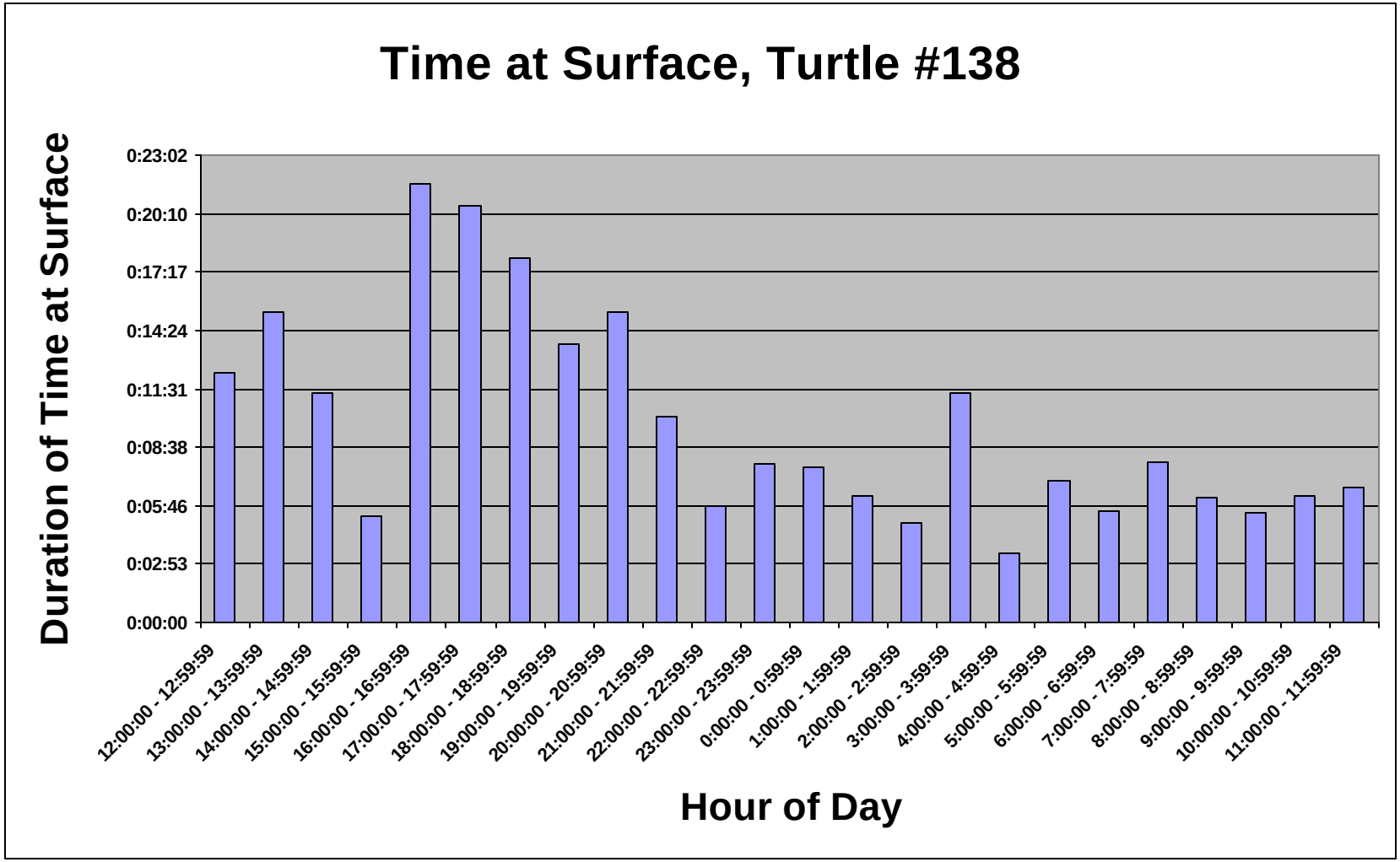

Figure19. Turtle #138 Surfacing Times, July 31 to August 1, 2003

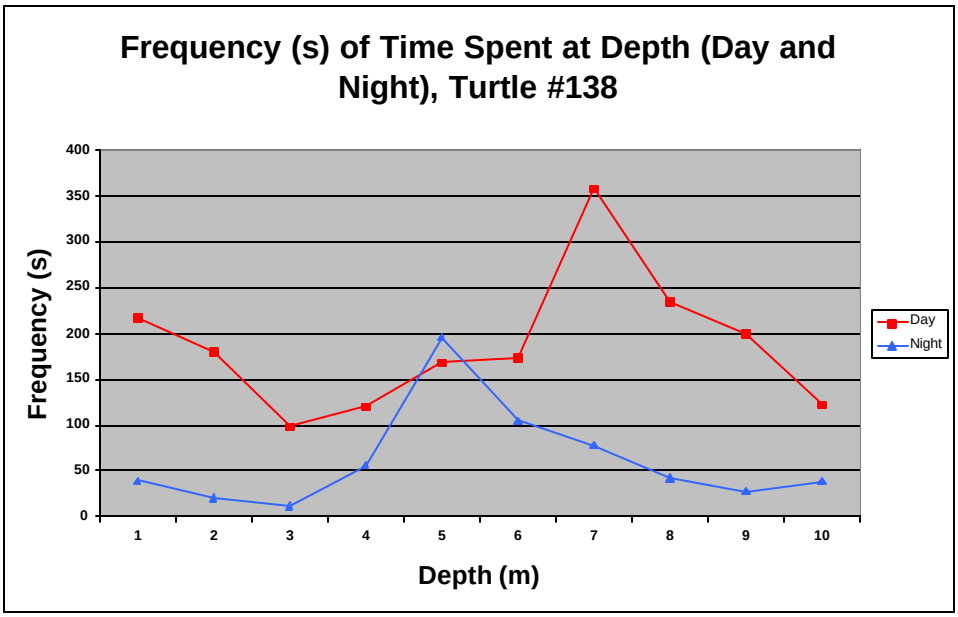

Figure 20 **Frequency if time spent at different depths for turtle # 138, Day vs. Night.**

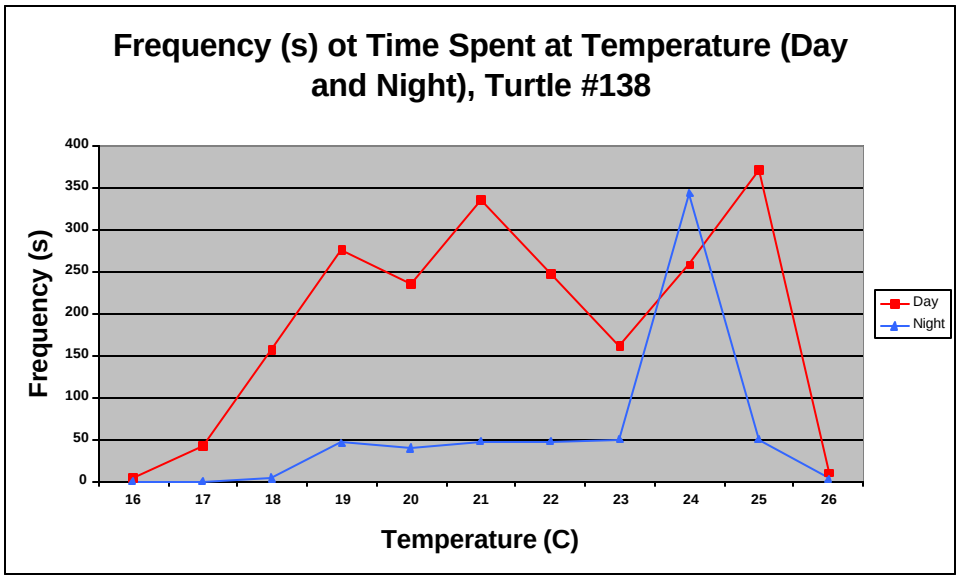

Figure 21 **Frequency if time spent at different temperatures for turtle # 138, Day vs. Night.**

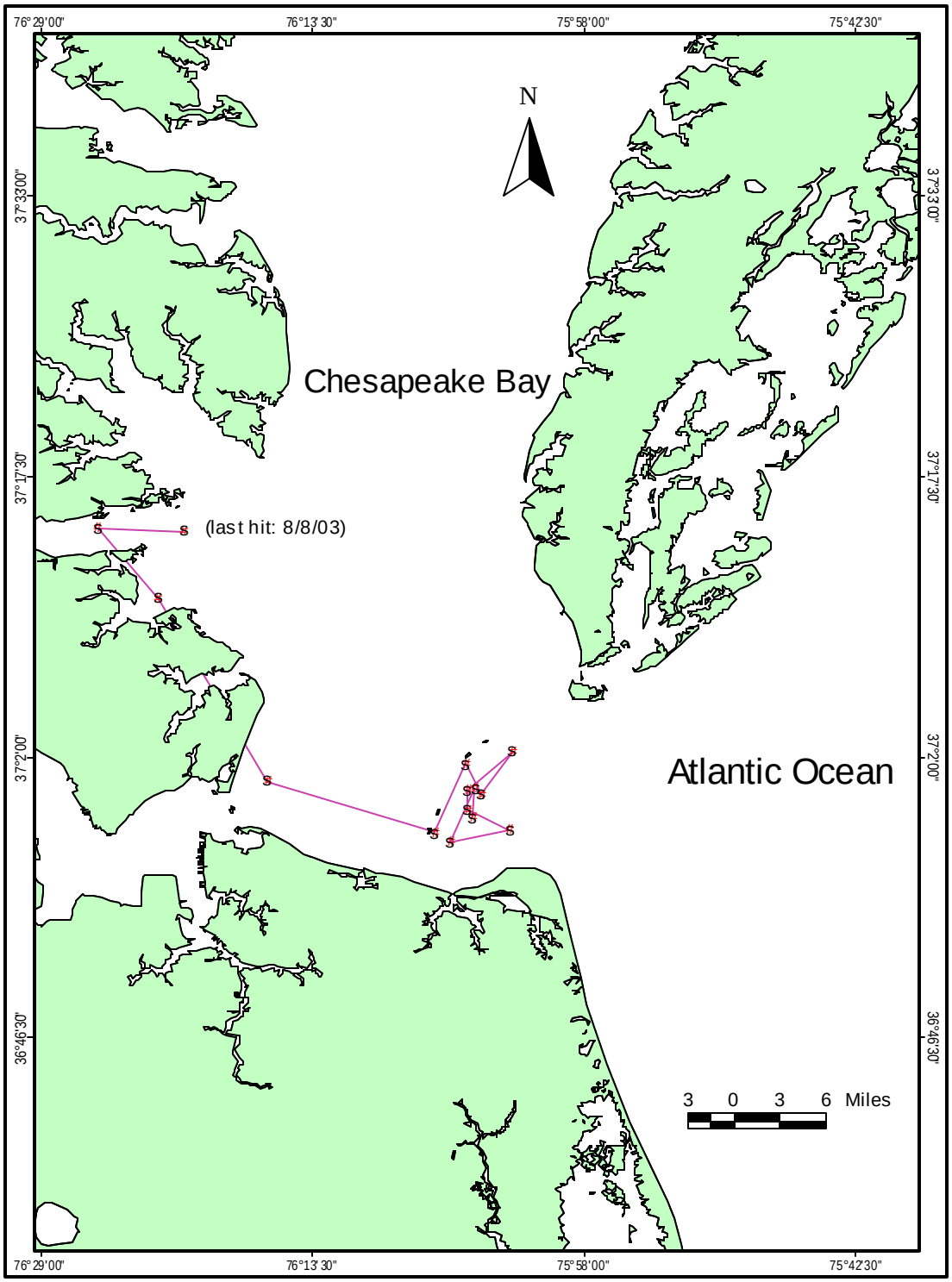

Figure 22. Satellite tracks of turtle #138, from July 31 to August 8, 2004.

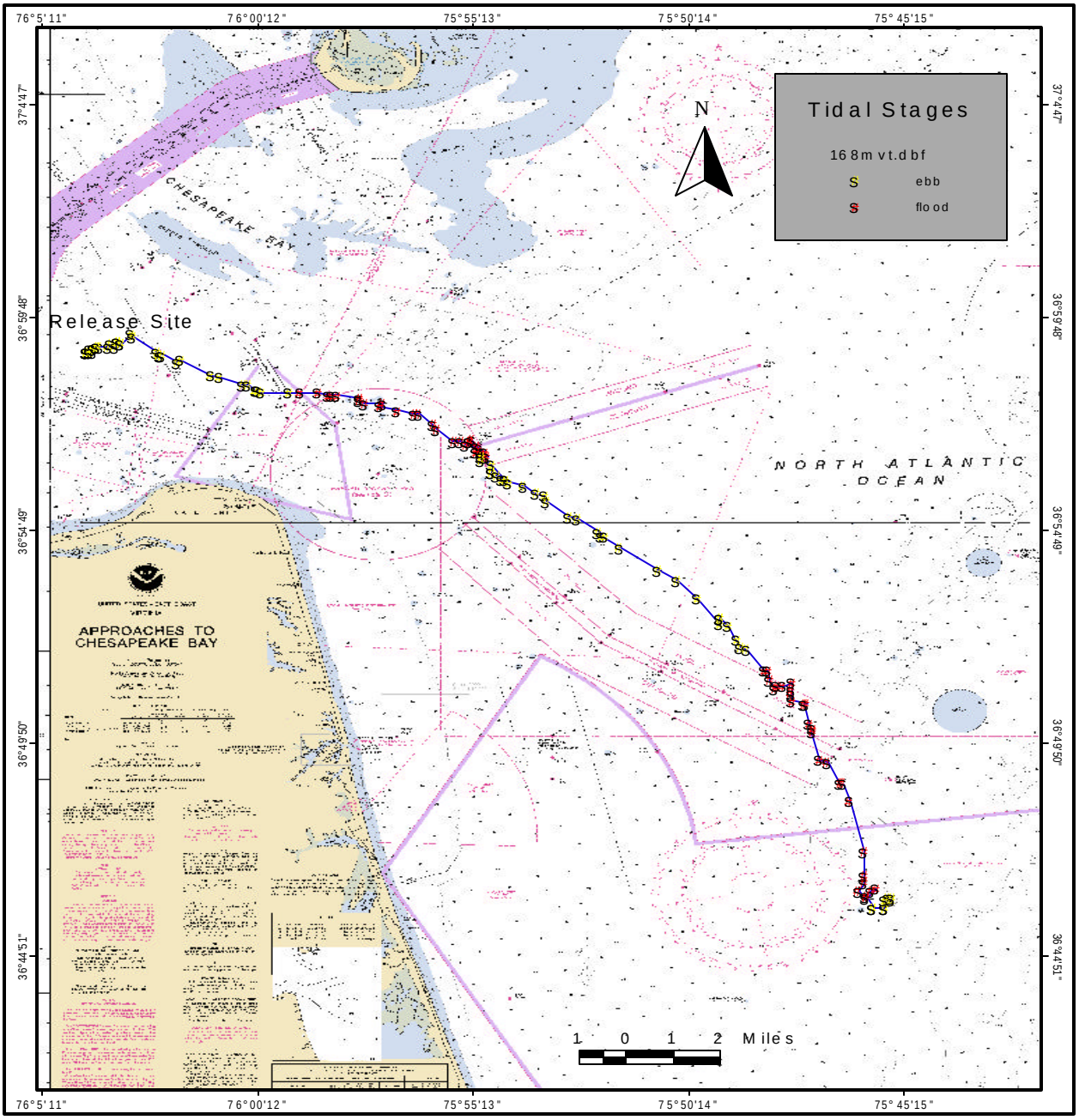

Figure 23. Post-release movements of turtle #168, radio tracked in the mouth of the Chesapeake Bay for 24-hours August 14 to 15, 2003.

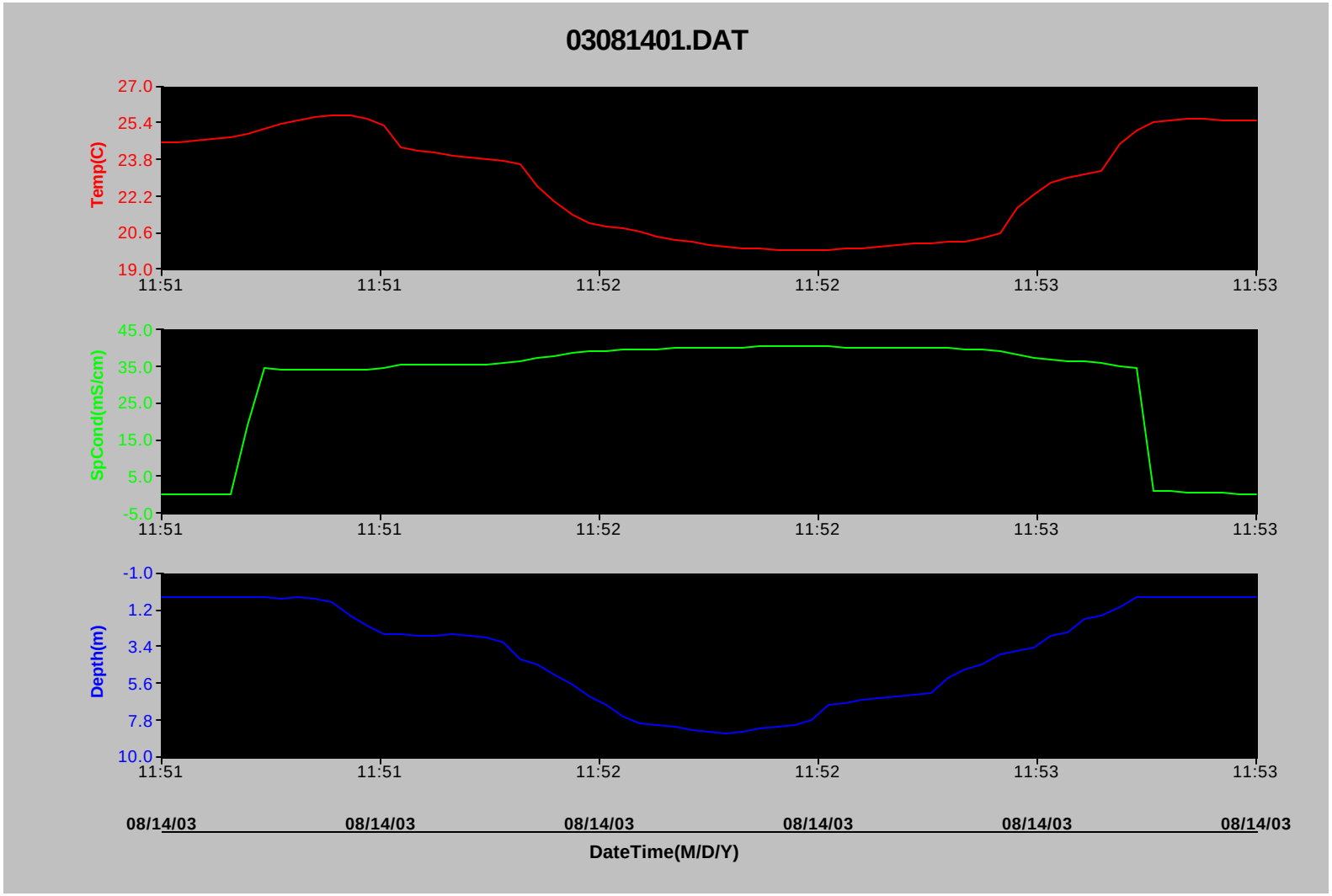

Figure 24. **Temperature, Conductivity and Depth Profile of release site for turtle # 168, August 14, 2003, ocean side of Chesapeake Bay Bridge Tunnel near Thimble Shoals Channel, Chesapeake Bay, VA.**

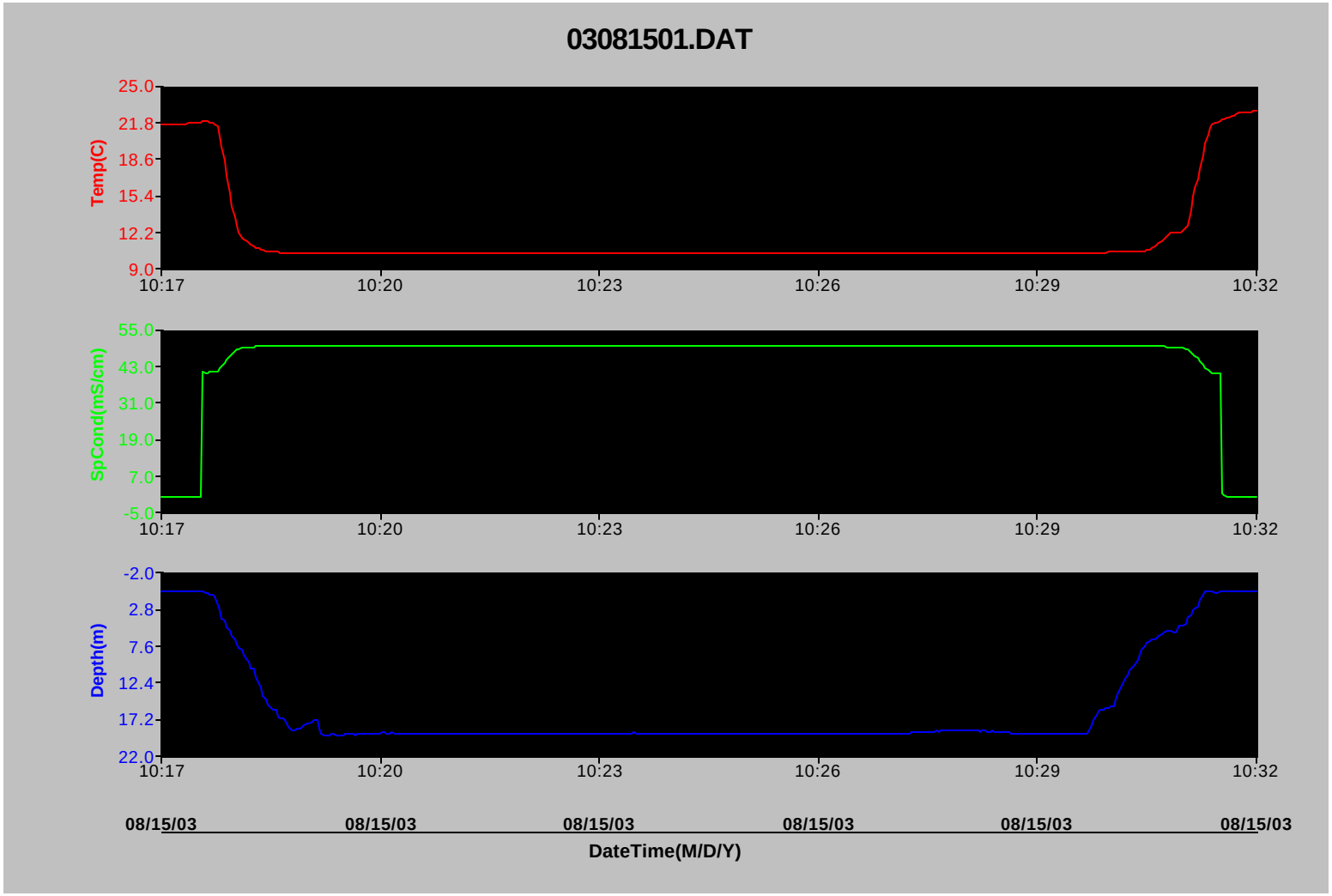

Figure 25. Temperature, Conductivity and Depth Profile east of Rudee Inlet, Virginia for radio track of turtle #168, August 14, 2003, Atlantic Ocean.

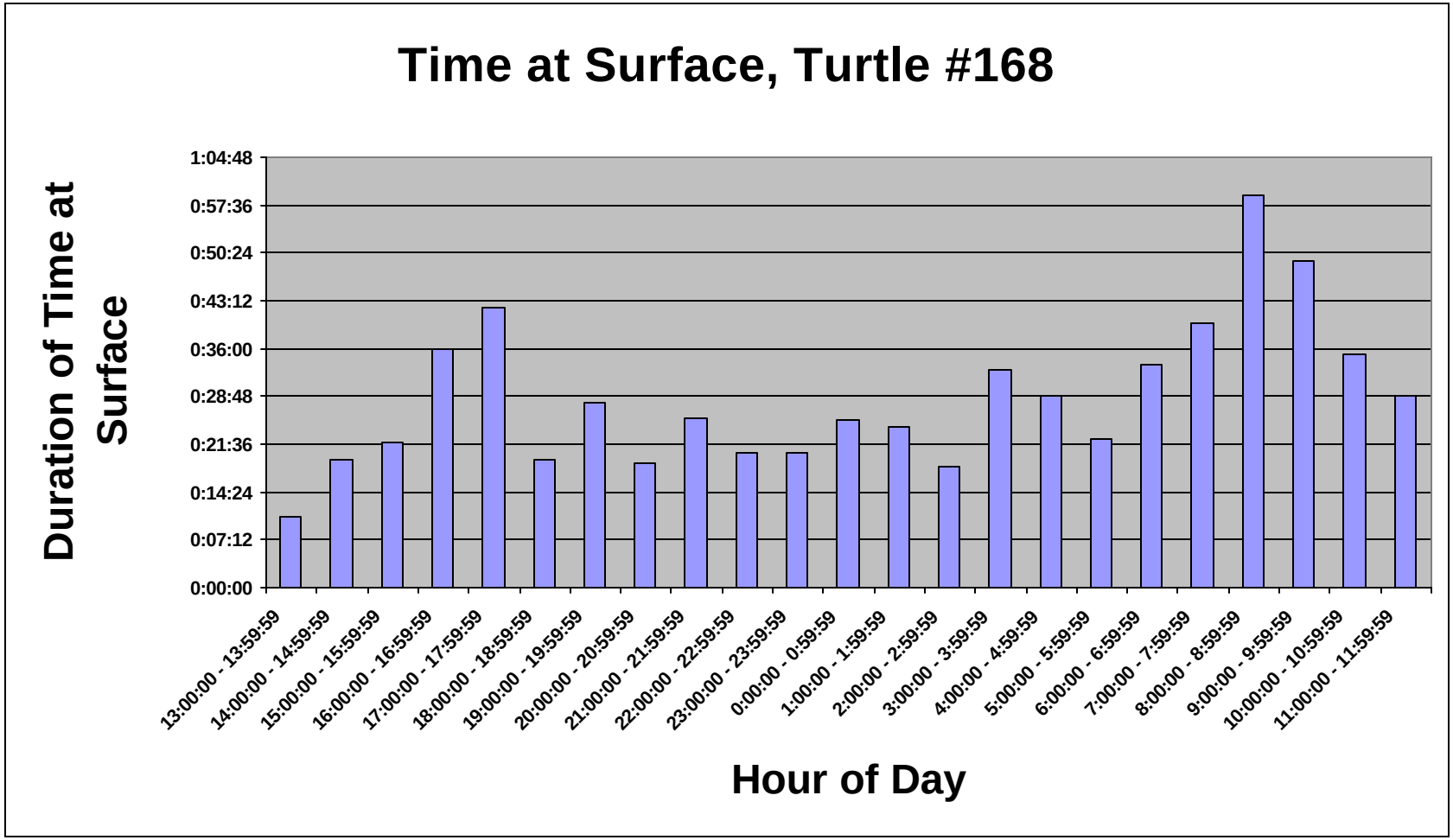

Figure 26. Turtle #138 Surfacing Times, August 14 to 15, 2003

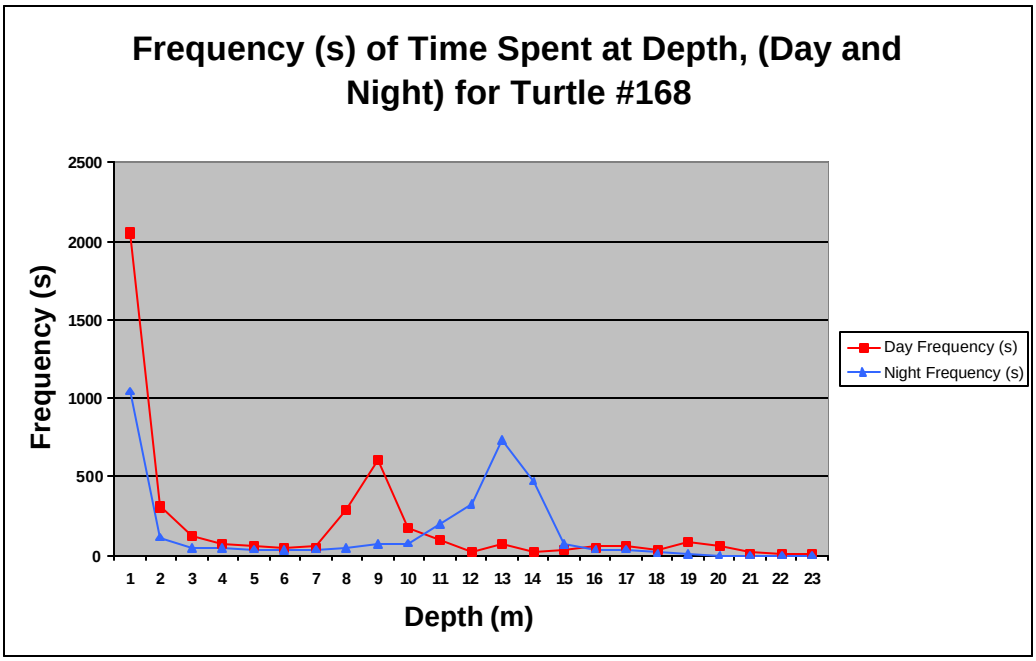

Figure 27. **Frequency if time spent at different depths for turtle # 168, Day vs. Night.**

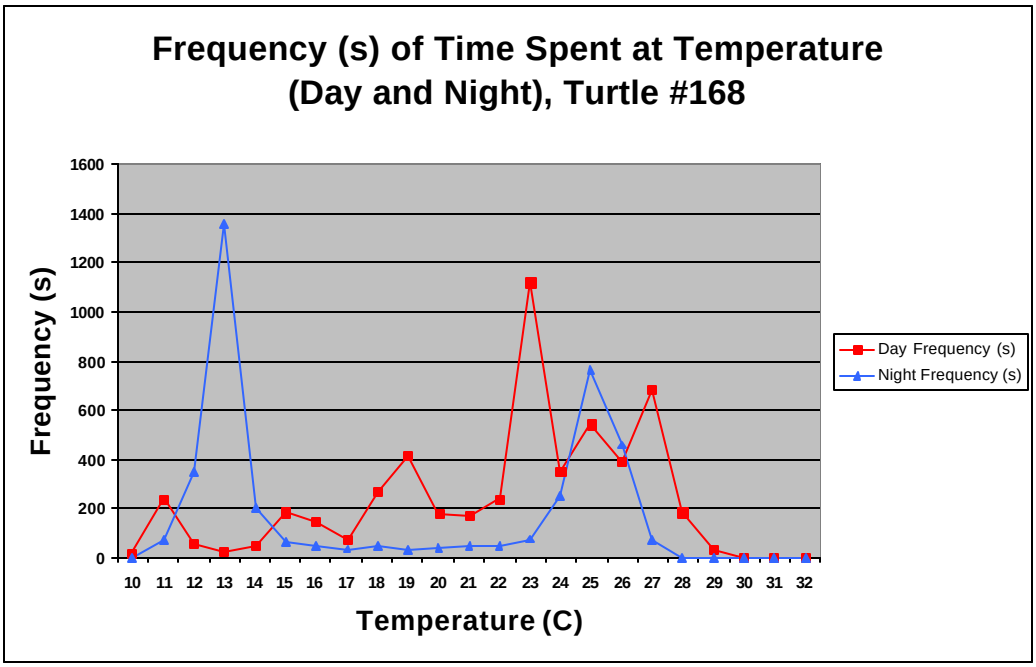

Figure 28. **Frequency if time spent at different temperatures for turtle # 168, Day vs. Night.**

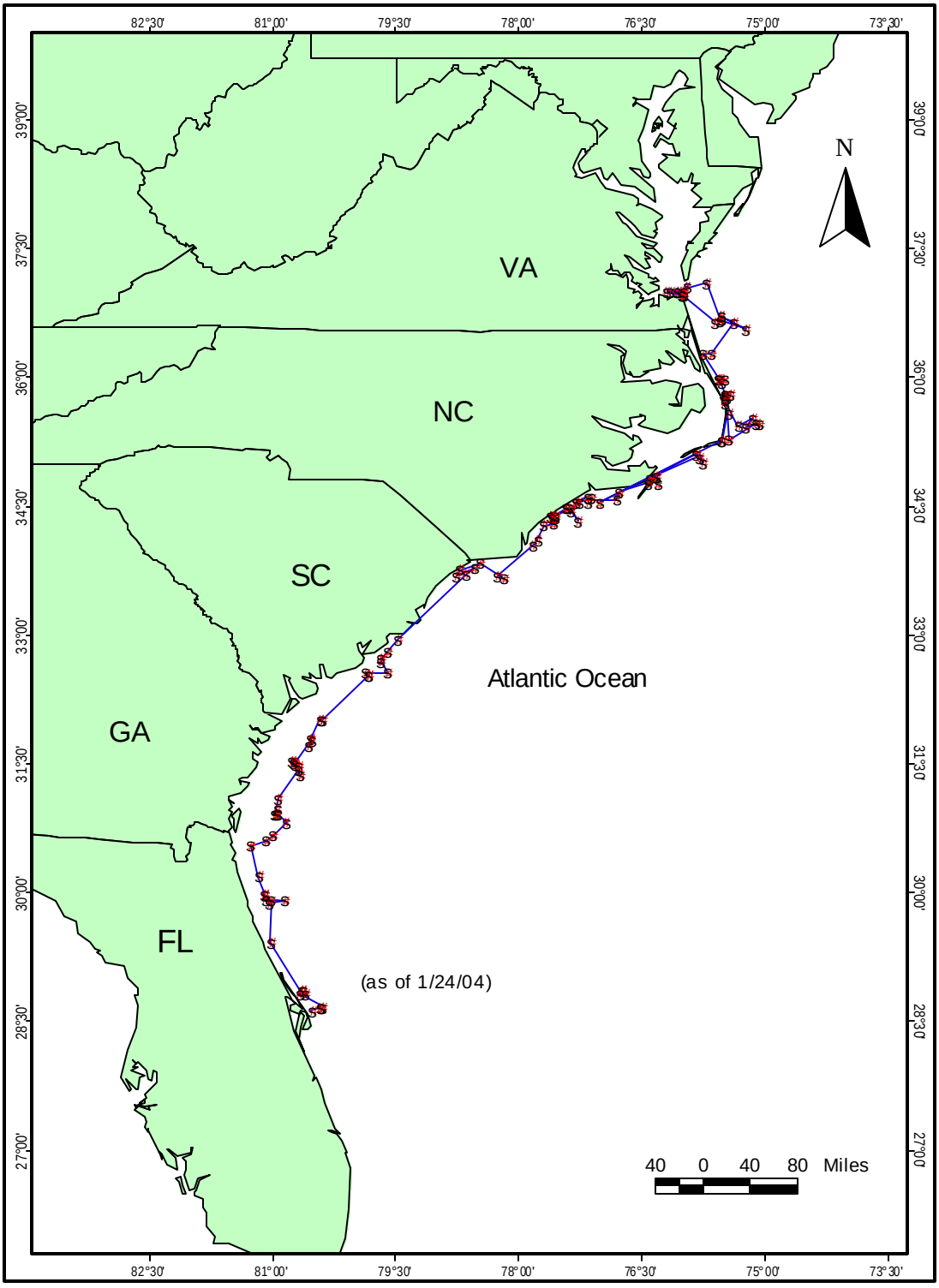

Figure 29. Satellite tracks of turtle #168, from August 18, 2003 to January 24, 2004.

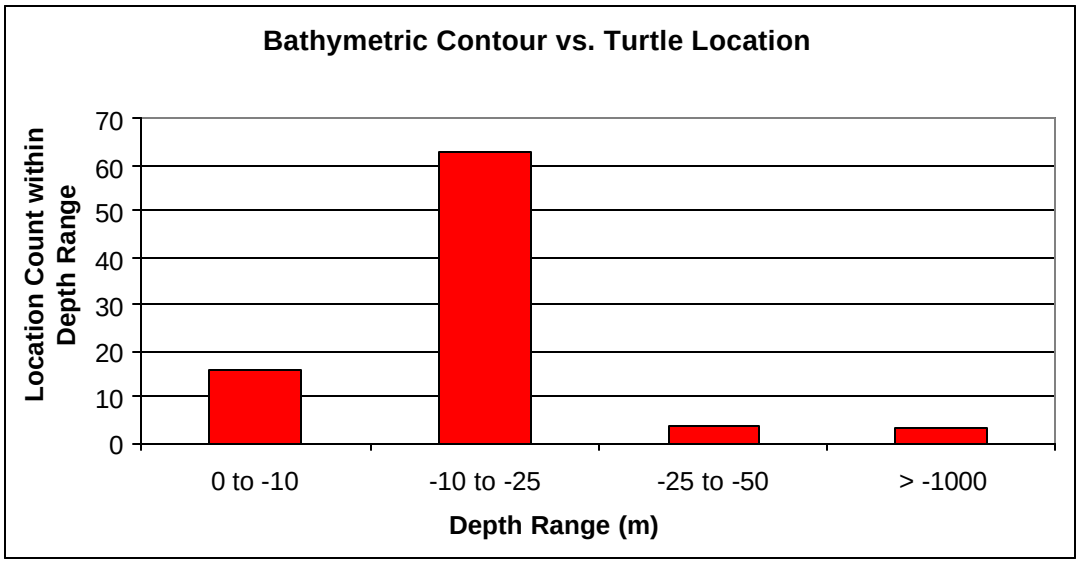

Figure 30. **Counts of satellite telemetry locations for turtle # 168 overlaid on NOAA GOES SST datasets from the NOAA NESDIS archives. Data generated by Maptool (seaturtle.org, 2002)**

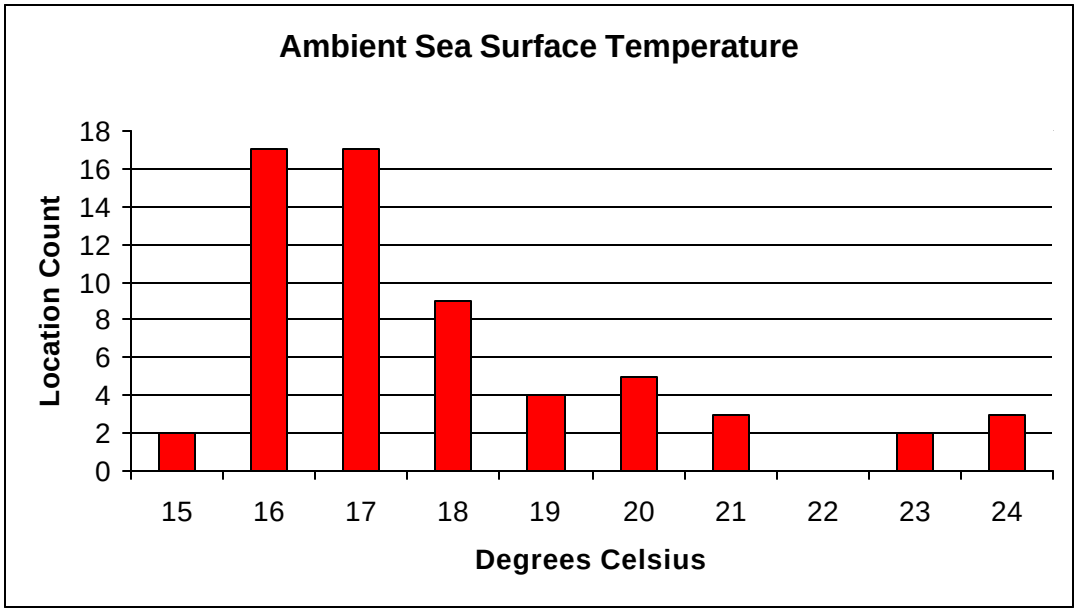

Figure 31. **Counts of satellite telemetry locations for turtle # 168 overlaid bathymetry datasets. Data generated by Maptool (seaturtle.org, 2002)**

Figure 32. **Satellite tracks of turtle #41135, from October 22 to November 6, 2003. Map generated by Maptool (seaturtle.org, 2002).**

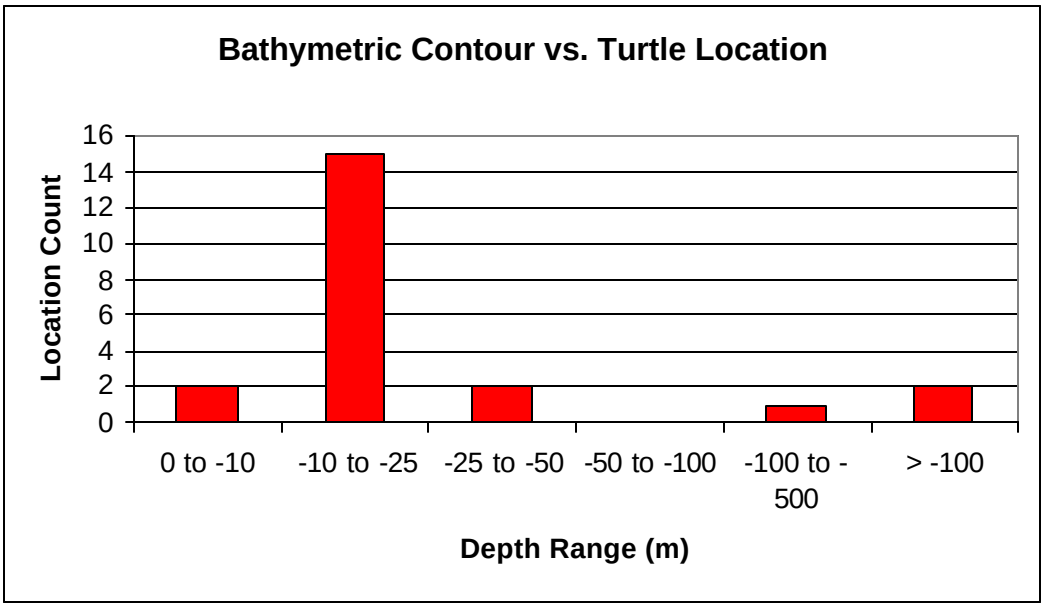

Figure 33. **Counts of satellite telemetry locations for turtle # 41335 overlaid on NOAA GOES SST datasets from the NOAA NESDIS archives. Data generated by Maptool (seaturtle.org, 2002)**

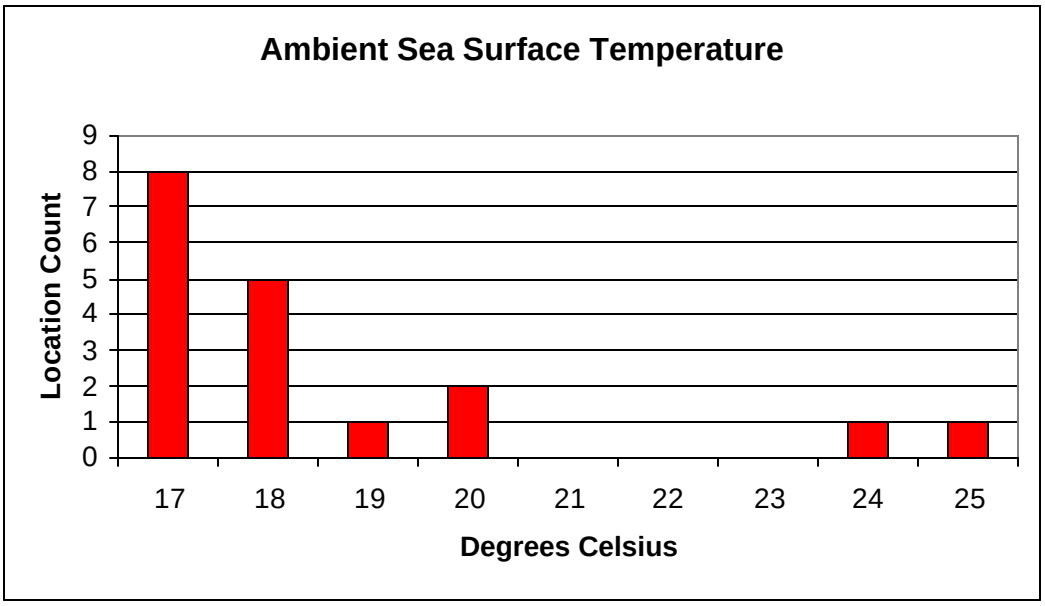

Figure 34. **Counts of satellite telemetry locations for turtle # 41335 overlaid bathymetry datasets. Data generated by Maptool (seaturtle.org, 2002)**

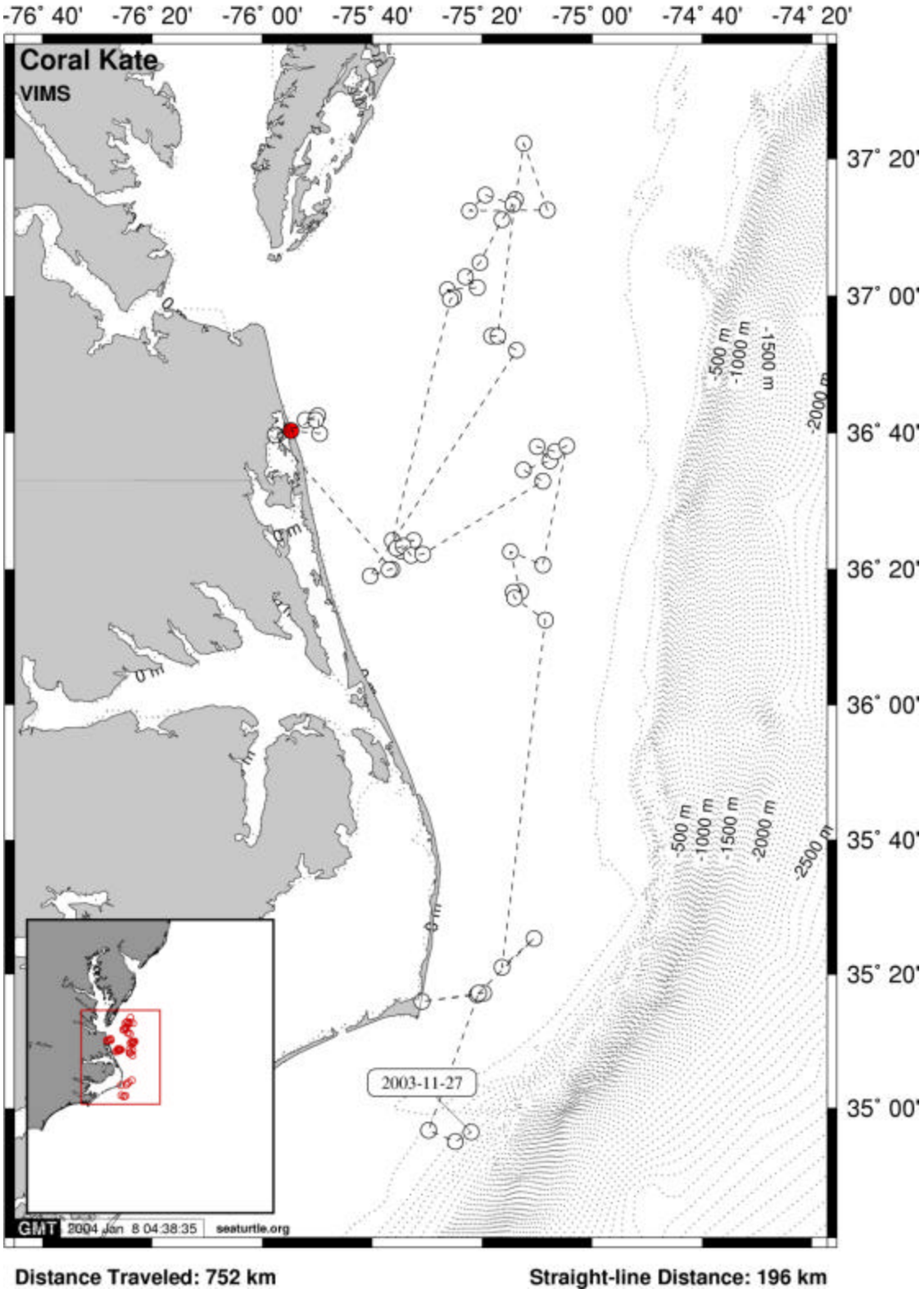

Figure 35. **Satellite tracks of turtle #41136, from October 22 to November 27, 2003. Map generated by Maptool (seaturtle.org, 2002).**

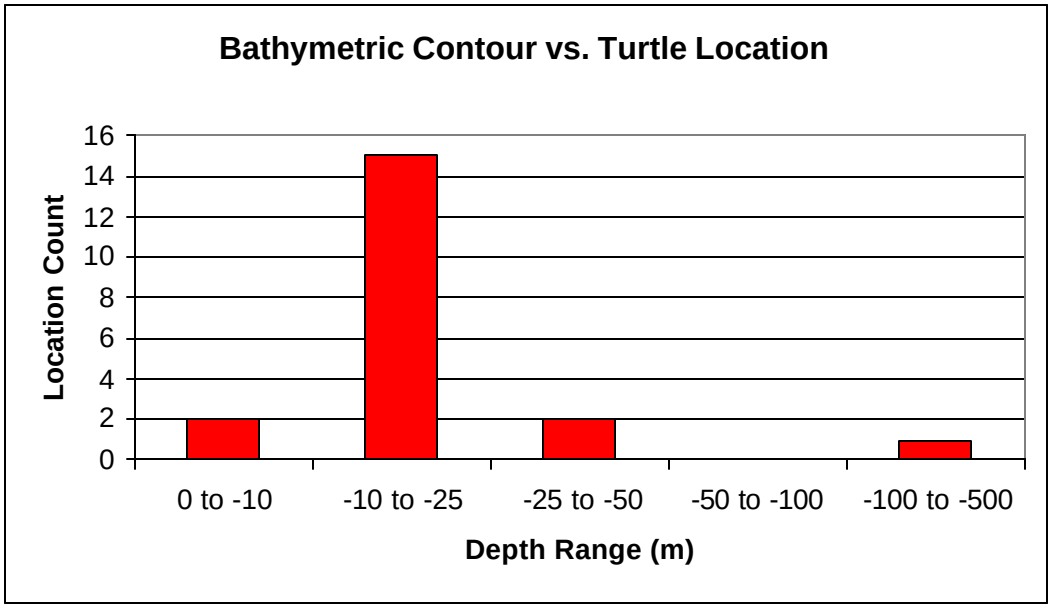

Figure 36. **Counts of satellite telemetry locations for turtle # 41336 overlaid on NOAA GOES SST datasets from the NOAA NESDIS archives. Data generated by Maptool (seaturtle.org, 2002)**

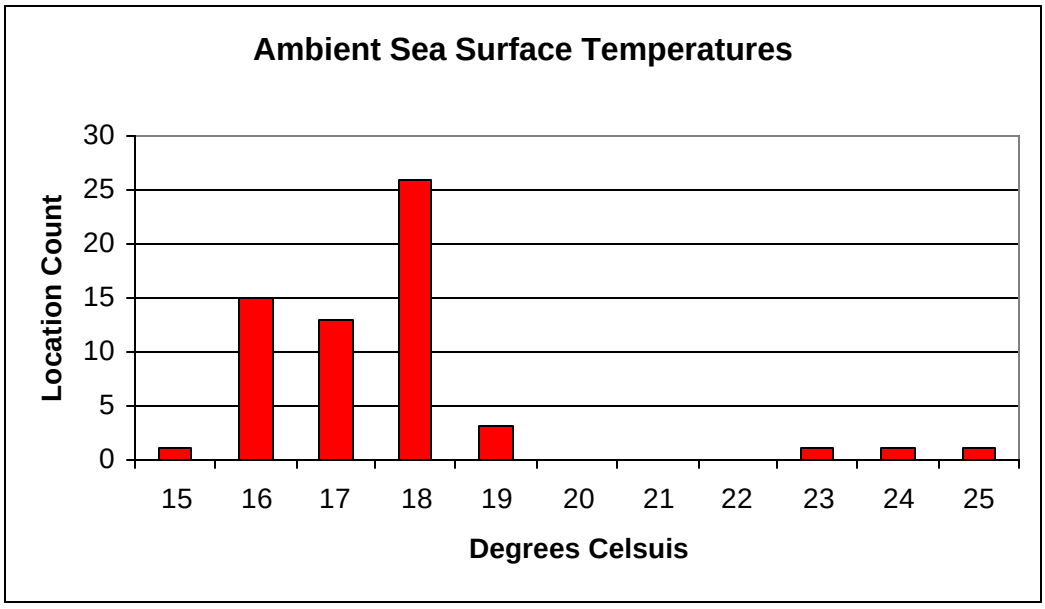

Figure 37. **Counts of satellite telemetry locations for turtle # 41336 overlaid bathymetry datasets. Data generated by Maptool (seaturtle.org, 2002)**